Comparison of isotopic signatures in speleothem records and model simulations for the past millennium

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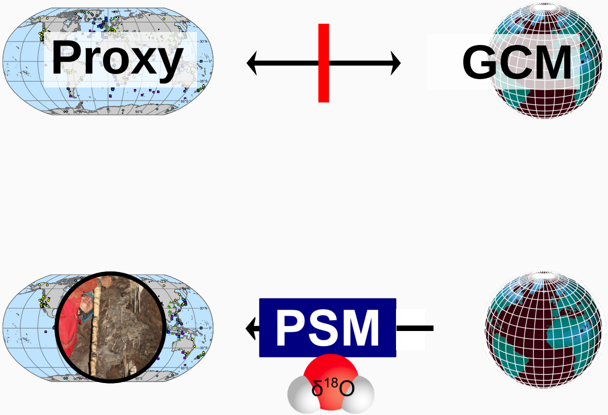
Model Data Comparison: HadCM3 vs. Speleothems



Proxies (e.g. $\delta^{18}O$ in ice cores/speleothems) hold past climatic information but the interpretation is not always straight-forward.

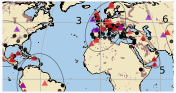
GCMs need to be tested against observations or paleoclimatic data from proxies.

In this model-data comparison, we want to test for a model's capability to resolve variability on different time scales and for speleothems to capture it

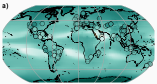
(e.g with Proxy System Models (PSM), iGCMs and a large speleothem dataset)

Figure modified from Rehfeld,2019 (Water molecule Sakurambo, Wiki Commons, Public domain), PSM as in Evans et al. Quat. Sci 76, 2013 and Dee et al. J. Adv. Model. Earth Syst. 7, 2015

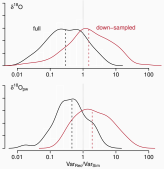
Quick summary for a fast run-through



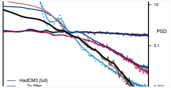
We compare isotopic signatures of a large global speleothem database... → **SISALv2**



... to HadCM3 PMIL isotope enabled simulations → We find only a small offset btw. simulated $\delta^{18}O$ and $\delta^{18}O_{calcite}$ after conversion to drip water equivalents



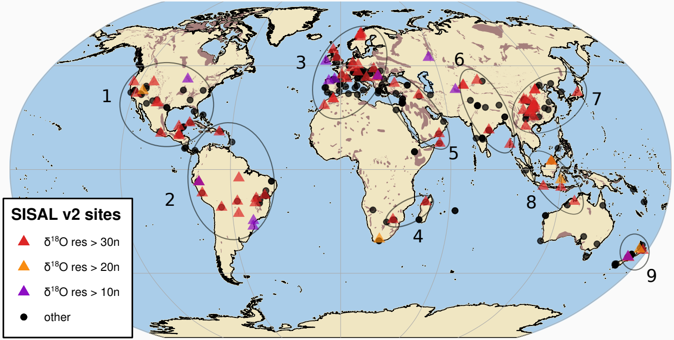
Tot. variances in records is twice as high, very low 100y variance in sim. → Low SNR in records, small internal variability on centennial time scale in simulation



Karst filter of realistic time scale (∼3y) leads to equivalent Power Spectral Density → Promising for future PSM application

SISALv2 from Comas-Bru et al. 2020 under review in Earth System Science Data

Proxies: SISALv2 database $\delta^{18}O$ filtered for past millennium



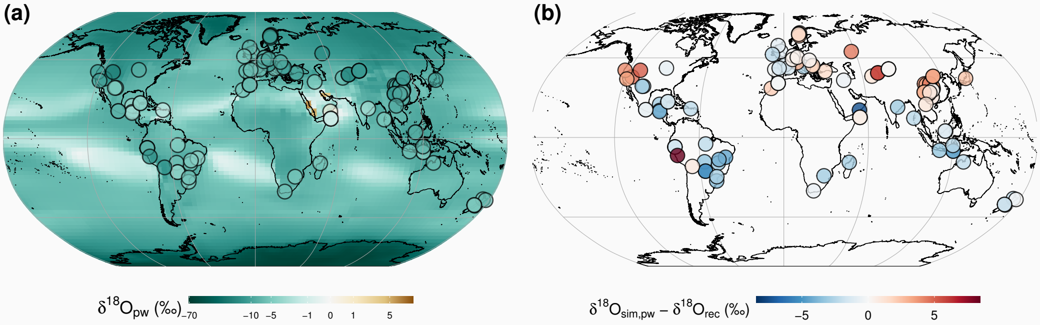
Criteria: more than 2 datings and more than 10 (20/30, depending on analysis) $\delta^{18}O_{calcite}$ measurements within a 600y period during the last millennium

Distance based clustering: 1: N-America (12), 2: S-America (13), 3: Europe + N-Africa (22), 4: S-Africa (2), 5: Middle East (6), 6: India + centr.-Asia (8), 7: E-Asia (19), 8: SE-Asia (4), 9: New Zealand (3), (30n criterion)

From 691 entities of 294 sites, 108 entities from 90 sites meet the filter criteria. Analysis is also done on a cluster level (9 clusters). Calcite $\delta^{18}O$ is converted to drip-water equivalents.

Karst data (brown) from Williams and Ford, Zeitschrift für Geomorphologie, 2006, **SISALv2 database:** 600y within PMIL, more than 2 age and more than 10 $\delta^{18}O$ measurements (Comas-Bru et al. 2020 under review in Earth System Science Data). **Drip-water equivalents:** as in Comas-Bru et. al, Clim. Past 2019, **Figure:** Bühler et al. 2020 in prep.

iGCM: HadCM3 PMIL. We see only small offset to annual $\delta^{18}O_{pw}$



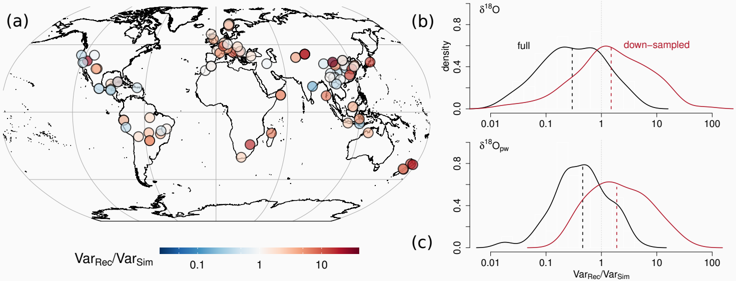
Mean offset between simulated (sim) prec.-weighted $\delta^{18}O$ and drip water equivalents of records (rec): $\delta^{18}O_{pw} - \delta^{18}O_{dw.eq} = -0.07‰[-4.27, 4.36$ 90% CI].

Bühler et al. 2020 in prep.

Variance of $\delta^{18}O_{dw.eq}$ larger than simulated $\delta^{18}O$

Variance ratio record/simulation (down-sampled)

median = 1.8 [0.31, 17.72 90 % CI]



blue: Simulation shows more variance, red: records show more variance

"Full": $\delta^{18}O_{pw}$ with yearly resolution, **"Down-Sampled":** yearly resolution to record resolution.

Even though the variance of the 'full' simulation is higher, this is only on short time scales. The 'full' simulation has very little variance on centenial time scales.

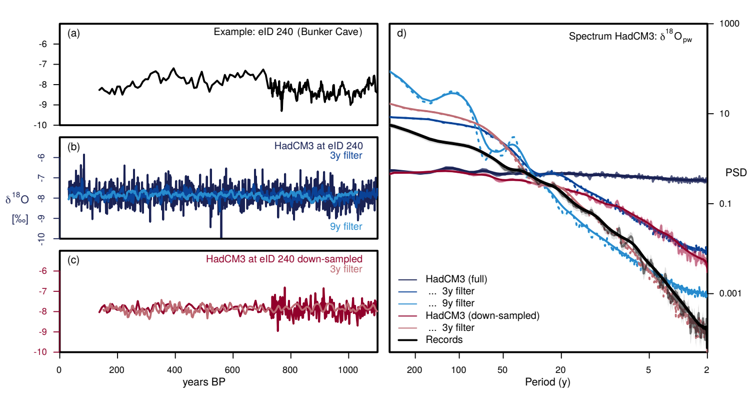
We see high heterogeneity in variances between different records compared to simulated variances at the cave site, indicating a strong influence of cave internal processes.

We find no relationship between offset (previous slide) and variance ratio and cannot distinguish regional patterns.

Bühler et al. 2020 in prep.

Variability Analysis shows potential for Proxy System Model

Karst filter of realistic time scales (3y) leads to equivalent PSD of record and down-sampled mean spectra on short time scales.



(a-c): example time series eID240 at Bunker cave. High variability on short time scales in full simulation(b), and higher variability on longer time scales in records noticable (a).

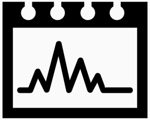
(d): Mean spectrum of yearly resolution (full) HadCM3 (blue) at cave site: white noise (flat)

Down-sampled to record resolution HadCM3 (red) at cave site: smaller variability on short time scales. Increasing spectral slope as in record.

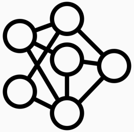
Mean spectrum of records (black) : even less variable on short time scales, but more variable on longer time scales.

Example record data: Bunker cave eID240 in SISALv2 from Fohlmeister et al. Clim. Past, 2012; **Figure:** Bühler et al. 2020 in prep.

Conclusion & Outlook



Similarity: small offset and 2× higher variance in records → Higher total variance indicates lower SNR in records



Further studies in prep: network and main climatic driver analyses → Low representativity of entities on regional level through low SNR

Use filter results for PSM implementation and calibration at drip water sites → Drip water database, include cave specific parameters

Extend to LGM and include more models → Study variability on longer time scales and differences between models

Icons from https://www.flaticon.com/de/autoren/freepik or modified from Rehfeld, 2019

Acknowledgments

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