Spelothems can inform climate field reconstructions by using multi-time scale PaleoDA with isotope-enabled GCMs.

**STARTING POINT**
- Spelothems & ice cores record decadal to centennial climate variability
- Last millennium reconstructions as LMR [1] or PHYDA [2] mostly rely on tree-rings from the Northern Hemisphere
- $\delta^{18}O$ from spelothems can hardly be calibrated to instrumental temperature/precipitation due to coarse temporal resolution
- Existing Paleoclimate Data Assimilation reconstructions do not systematically include spelothems
- Spelothem data can potentially fill tropical proxy data deserts

**LEADING QUESTIONS**
- Does using low-resolution proxy records and a multi-time scale approach improve the reconstruction of temporal variability?
- How do individual archive types contribute to the reconstruction?
- How do model differences and biases affect the reconstructions?

**RESULTS**
- Comparable GMT signals, mainly from the ice cores
- South American hydroclimate reconstruction shows potential of including spelothems
- Larger variability than LMR [1]
- Prior dependency: different $\delta^{18}O$-surf/prec sensitivity

**WORK IN PROGRESS**
- Include other proxy archives from PAGES2k, Iso2k, …
- Which climate phenomena can our reconstruction help understand (SAMS, SAM, ITZC shift, …)?
- Explore methodological uncertainties and covariance structures of models
- Best procedure to capture them?
Poster appendix for Climate fields of the last millennium from terrestrial climate archives and isotope-enabled GCMs

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6 Abbreviations

1 References on poster

1.1 Numbered references:


1.2 Model data references can be found in


1.3 Proxy record databases

**SISALv2**

**Iso2k**

Further proxy record databases used for bottom right figure (and not for reconstructions performed for the poster)

**Pages2k**

**Breitenmoser tree-ring dataset**

**PHYDA database (for Breitenmoser tree-ring dataset)**

2 Methodology

A thorough treatment of the Paleoclimate Data Assimilation method can be found in the master's thesis of the presenting author, which is publicly available under the following link: https://heibox.uni-heidelberg.de/f/215b873aaee154346b217/. It also comprises a comprehensive description of the reconstruction parameters for the global mean temperature and South America reconstructions.

A manuscript for a reconstruction focussed on tropical South America is currently in preparation.
3 Temporal variability spectra

To assess the skill of the multi-time scale PaleoDA algorithm to reconstruct temporal variability, Pseudoproxy experiments (PPEs) have been performed over 1000 simulated years. For each experiment, 200 terrestrial pseudoproxy locations have been selected. The global mean temperature has then been reconstructed based on the $\delta^{18}O$ values from these locations. A Signal-to-Noise ratio of 0.5 has been chosen for the creation of the noisy time series. The following number of pseudoproxy locations have been selected for the individual experiments and time scales:

- Annual experiment (1): 200 pseudoproxies
- 1,5: 100 annual pseudoproxies, 100 5-year averaged pseudoproxies
- 1,20: 100 annual pseudoproxies, 100 20-year averaged pseudoproxies
- 1,5,20: 100 annual pseudoproxies, 50 5-year averaged pseudoproxies, 50 20-year averaged pseudoproxies

The authors are aware, that the number of employed data points over the whole reconstruction period is not equal in the different experiments. PPEs with an adjusted number of locations have been performed in the master’s thesis of the presenting author (Choblet, 2022). Each experiment has been repeated 100 times with different prior ensemble members (100) and pseudoproxy locations.

The spectra have been generated with the multi-taper method (mtm) of the Pyleoclim package (Khider et al.). The GMT curves have been detrended, but not standardized, which is important to compare the absolute variability of each time series.

3.1 ECHAM spectra

![Global mean temperature from Echam](Figure 1. Power spectral densities of reconstructed global mean temperature using pseudoproxies on multiple time scales. The model that has been used as a prior is ECHAM. The pseudoproxies have been generated from $\delta^{18}O$ with an SNR of 0.5 and the PSM-light configuration for the simulated $\delta^{18}O$ at 200 proxy record locations. The noise has been added to the pseudo proxy records after averaging the time series to the higher time scales.)
3.2 iHadCM3 spectra

Figure 2. Same as figure 1 for iHadCM3.

3.3 isoGSM spectra

Figure 3. Same as figure 1 for isoGSM.
3.4 GISS spectra

![GISS spectra](image)

**Figure 4.** Same as figure 1 for GISS.

4 Global mean temperature plots

The following figures are part of Choblet (2022).

![Global mean temperature plots](image)

**Figure 5.** The reconstructed GMTs from the individual and joint SISAL (speleothems) and Iso2k (ice cores) databases in comparison to the LMR and PHYDA reconstructions are shown in the left panel. The uncertainties of the reconstructions are shown in the right panel. The periodicity is an artefact from the prior block in the multi-time scale approach. The time series have been low-pass filtered with a 50 year Butterworth filter.
Figure 6. Latitudinal mean temperature anomalies over time (Hovmöller diagram). The upper left panel shows the LMR reconstruction, the upper right panel the results from the MME reconstruction using both the speleothems and ice cores. The lower panel show the reconstructions using only speleothems (SISAL) and ice cores (Iso2k). In comparison to the top right figure of the poster, the time series have not been filtered. The apparent coarser resolution of MME in comparison to LMR stems from the multi-time scale approach. 851-1849CE was used as the reference period.
**Figure 7.** Heat map visualizing the correlation between the time series in top right figure of the poster. The correlations are computed separately for the PI (left panel) and the CWP (right panel). The time series have not been detrended to assess similarity including the cooling and warming trends. No filtering of the signals has been performed. The CWP evaluation also includes the correlation with the observational GMT from the Berkeley Earth dataset (BE) (Rohde and Hausfather). *mme_sisal* and *mme_iso* refer to the multi model ensemble reconstructions with the separate SISALv2 and Iso2k database records. The 95% confidence intervals of the correlations can be found in Choblet (2022).

**Local correlation of MME and LMR**

**Figure 8.** Correlation fields between the MME reconstruction (using both databases) and the LMR. The left panel shows the correlation for the PI (800-1850CE) and the right panel for the CWP (1850-1999CE). The local time series have not been filtered. The time series have not been detrended. The stippling indicates non-significant correlations (p>0.05).
5 South America Plots

In the following, the central right plot on the poster, which shows the monsoon index strength and MCA-LIA difference is shown for the individual model priors (center panels) and single model prior reconstructions (right panels).

5.1 iCESM

![Diagram showing South American Monsoon with MCA and LIA comparisons and precipitation changes over time.](image)
5.2 ECHAM

South American Monsoon
(5°S–17.5°S/72.5°W–47.5°W mean)

LIA - MCA
(ECHAM prior)

LIA - MCA
(ECHAM reconstruction)

5.3 iHadCM3

South American Monsoon
(5°S–17.5°S/72.5°W–47.5°W mean)

LIA - MCA
(iHadCM3 prior)

LIA - MCA
(iHadCM3 reconstruction)
5.4 isoGSM

South American Monsoon (5°S–17.5°S/72.5°W–47.5°W mean)

LIA - MCA (isoGSM prior)

LIA - MCA (isoGSM reconstruction)

5.5 GISS

South American Monsoon (5°S–17.5°S/72.5°W–47.5°W mean)

LIA - MCA (GISS prior)

LIA - MCA (GISS reconstruction)
6 Abbreviations

CE  Common Era
DA  Data assimilation

ECHAM  ECHAM5/MPI-OM climate model
GCM  General Circulation Model
GISS  Goddard Institute for Space Studies atmospheric general circulation model
GMT  Global mean temperature
iCESM  isotope-enabled version of the Community Earth System Model

HadCM3  isotope-enabled version of the Hadley Centre Coupled Model

Iso2k  Database of water isotope values for the past two millennia (Konecky et al.)
isoGSM  Isotopes-incorporated Global Spectral Model
ITCZ  Intertropical Convergence Zone
SACZ  South Atlantic Convergence Zone

K  Kelvin
LIA  Little Ice Age
LMR  Last Millennium Reanalysis (Hakim et al.; Tardif et al.)
MCA  Medieval climate anomaly
MME  Multi model ensemble

PAGES2k  Database for temperature proxies during the last two millennia (Ahmed et al.; Emile-Geay et al.)
PaleoDA  Paleoclimate data assimilation
PHYDA  Paleo Hydrodynamics Data Assimilation product (Steiger et al.)
PPE  Pseudoproxy experiments
prec  Precipitation

PSD  Power spectral density
PSM  Proxy system model (Evans et al.)
SISALv2  Second version of the SISAL speleothem database (Comas-Bru et al.)
SNR  Signal-to-noise ratio
slp  Sea level pressure

tsurf  Surface temperature
References


