Pollen Palaeoclimate Networks quantify the similarity of pollen proxies on a global scale

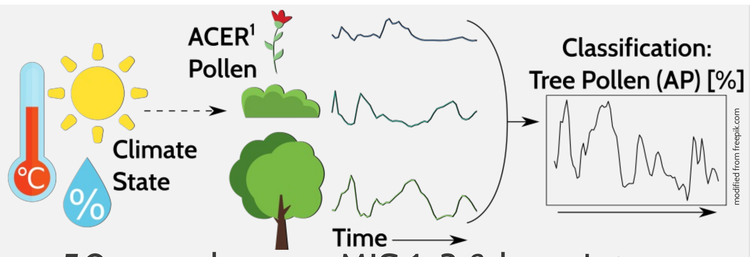
Moritz Adam[1], Carla Roesch[1], Martina Stebich[2], Nils Weitzel[1], Kira Rehfeld[1]

[1]Institute of Environmental Physics, Heidelberg; [2]Senckenberg Research Station Weimar

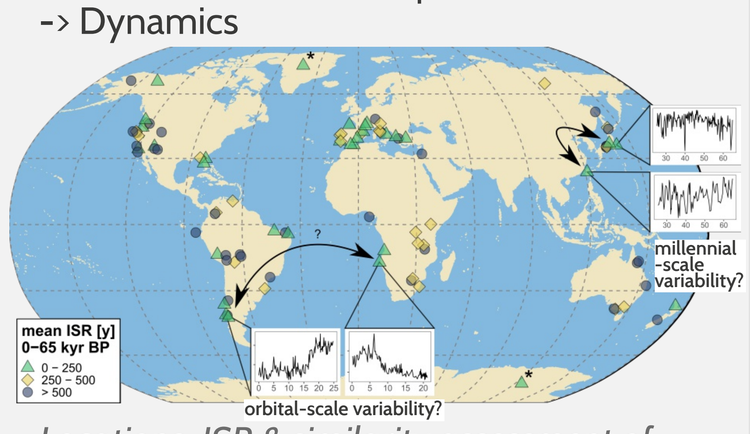
1 Motivation

Pollen records provide useful insights into the past climate at many mid- to low-latitudinal locations. Joint analyses are challenging given e.g. their irregular temporal sampling, and a non-uniform spatial distribution. In view of these challenges, we statistically examine the similarity of a global set of pollen records[1] on orbital and millennial time scales. Based on a palaeoclimate network (PCN) approach[2], we investigate spatial patterns of past climate changes during deglaciation and MIS 3.

2 Data, Methods



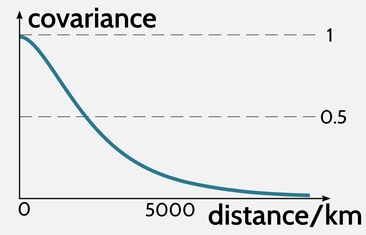
- 50 records cover MIS 1-3 & have inter-sample range (ISR) ≤ 300 years[3]
- Similarity measure: Gaussian kernel correlation[4] -> Network patterns[2] -> Dynamics



Locations, ISR & similarity assessment of ACER and NGRIP[5], EDC[6] isotope records (*)

3 Stochastic Reference Models

Significance of similarity scores?
-> Null model (NM) for noise
- NM = AR(1) x Matérn, box aggregation
- Temporal autocorrelation
- Spatial covariance[7,8] of records



NM component of spatial noise covariance

Impact of record resolution on PCN?
-> Artificial hybrid ice cores[9] (HIC) with signal-to-noise variance ratio (snvr) η

$$HIC \sim \alpha\, EDC + \kappa\, NGRIP + \eta\, NM$$

- Combined: NGRIP and EDC
- η and resolution factor μ variable with ACER irregularity

4 State Dependency, Similarity

- AP proxies: mostly decrease of precipitation during LGM
- Patterns agree with speleothem growth rates and model output (Fig. 1)

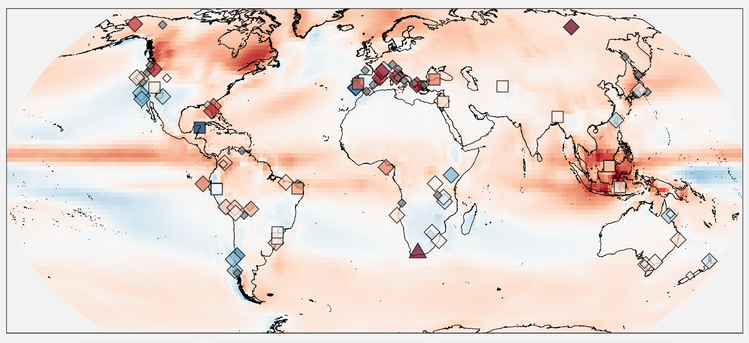


Fig. 1: Normalised anomalies PI-LGM: ACER AP proxies, SISAL speleothem growth rates[10-12] and precipitation from PMIP3[13]

Regional effects: inverted pacific AP trend (Fig. 2, 3) -> circulation shifted[14]

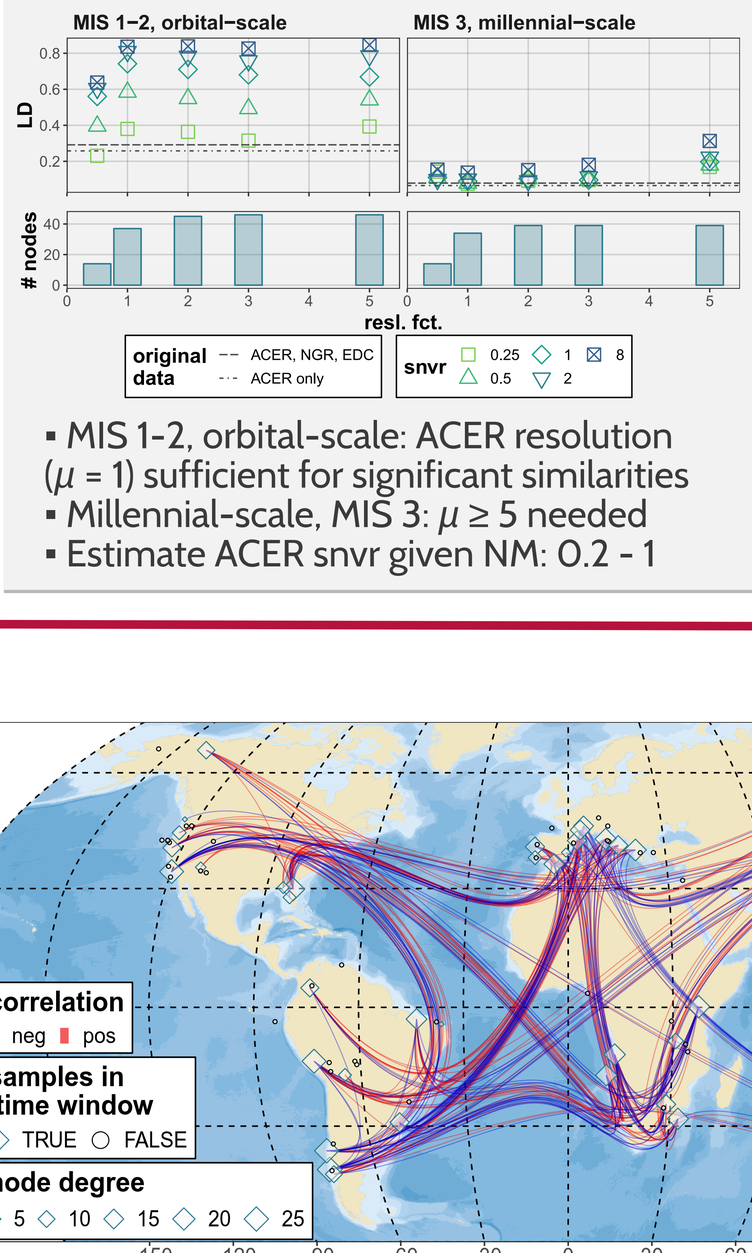
Fig. 2: Detail of AP-PCN, orbital variability, MIS 1-2

5 Record resolution

Link density (LD)[3]

$$= \frac{\text{Realised links}}{\text{Possible links}}$$

Fig.: Impact of resolution (units ACER resl.) and snvr on LD of HIC-PCN

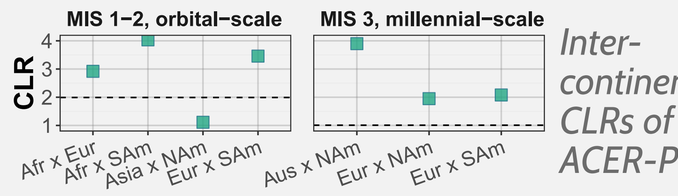


- MIS 1-2, orbital-scale: ACER resolution (μ = 1) sufficient for significant similarities
- Millennial-scale, MIS 3: $\mu \geq 5$ needed
- Estimate ACER snvr given NM: 0.2 - 1

6 Continental Patterns

Cross-link ratio (CLR)[3]

$$= \frac{\text{P (Inter-continental link)}}{\text{P (Link overall)}}$$



Inter-continental CLRs of ACER-PCN

Cross-Atlantic links pronounced: effect of resolution

7 Outlook

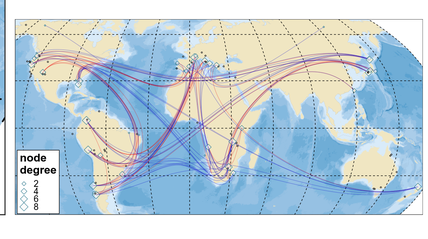
- Detailed network pattern analysis
- Systematic comparison of combined proxy set (AP, speleothems) and model output w.r.t. state and variability

Key Findings

Consistent state dependency of proxy data, deglaciation network patterns and climate model output.

Tree pollen comparable on orbital scales, but records not sufficiently resolved for significant millennial-scale similarities.

Fig. 3: Palaeoclimate networks for the deglaciation based on orbital-scale similarity (large), and for MIS 3 on a millennial scale (small)



Acknowledgements

Studienstiftung des deutschen Volkes

SISAL

Emmy Noether-Programm

DFG Deutsche Forschungsgemeinschaft

References

[1] Sanchez Goni, M.F. et al., ESSD 9, 679-695 (2017)
[2] Rehfeld K. et al., Clim. Dyn. 41, 3-19 (2013)
[3] Rehfeld, K. et al., Nonlin. Process. Geophys. 21, 691-703 (2014)
[4] Rehfeld, K. and Kurths, J., Clim. Past 10, 107-224 (2013)
[5] NGRIP Members, Nature 431, 147–151 (2004)
[6] EPICA Members, Nature 444, 195–198 (2006)
[7] Whittle, P., Biometrika 41.3-4, 434-449 (1954)
[8] Whittle, P., Bull. Int. Stat. Inst. 40.2, 974-994 (1963)
[9] Rohling, E.J. et al., QSR 28, 3291-3302 (2009)
[10] Atsawawaranunt et al. and SISAL working group members, ESSD 10, 1687-1713 (2018)
[11] Comas-Bru, L. et al. and SISAL working group members, Clim. Past 15, 1557–1579 (2019)
[12] Comas-Bru, L. et al. (in preparation)
[13] Taylor, K. et al., BAMS 93, 485-498 (2012)
[14] Kilian, R and Lamy, F., QSR 53, 1-23 (2012)

madam@iup.uni-heidelberg.de
uni-heidelberg.de/palaeoclimate-dynamics

STACY