BJERKNES CENTRE
for Climate Research

Climate analogs as input for ice sheet models during the glacial

TOBIAS ZOLLES[1,2], ANDREAS BORN[1,2]

[1] Department of Earth Sciences,University of Bergen
[2] Bjerknes Centre of Climate Research

BJERKNES CENTRE
for Climate Research

Proxy analog method

- Create a transient climate forcing
- Based on the agreement between proxy/instrumental data and model simulations
- Dynamically expandable with new climate model simulations
- Other variables than the proxy records available
- Physical consistency between the variables not broken

Pseudo-proxy tests of the analogue method to reconstruct spatially resolved global temperature during the Common Era

Juan José Gómez-Navarro[1,2,3], Eduardo Zorita[4], Christoph C. Raible[1,2], and Raphael Neukom[2,5]

[1]Climate and Environmental Physics, Physics Institute, University of Bern, Bern, Switzerland
[2]Oeschger Centre for Climate Change Research, University of Bern, Bern, Switzerland
[3]Department of Physics, University of Murcia, Murcia, Spain
[4]Institute of Coastal Research, Helmholtz-Zentrum Geesthacht, Geesthacht, Germany
[5]Institute of Geography, University of Bern, Bern, Switzerland

A spatiotemporal reconstruction of sea-surface temperatures in the North Atlantic during Dansgaard–Oeschger events 5–8

Mari F. Jensen[1], Aleksi Nummelin[2,3], Søren B. Nielsen[4], Henrik Sadatzki[1], Evangeline Sessford[1], Bjørg Risebrobakken[5], Carin Andersson[5], Antje Voelker[6], William H. G. Roberts[7], Joel Pedro[8], and Andreas Born[1,9,10]

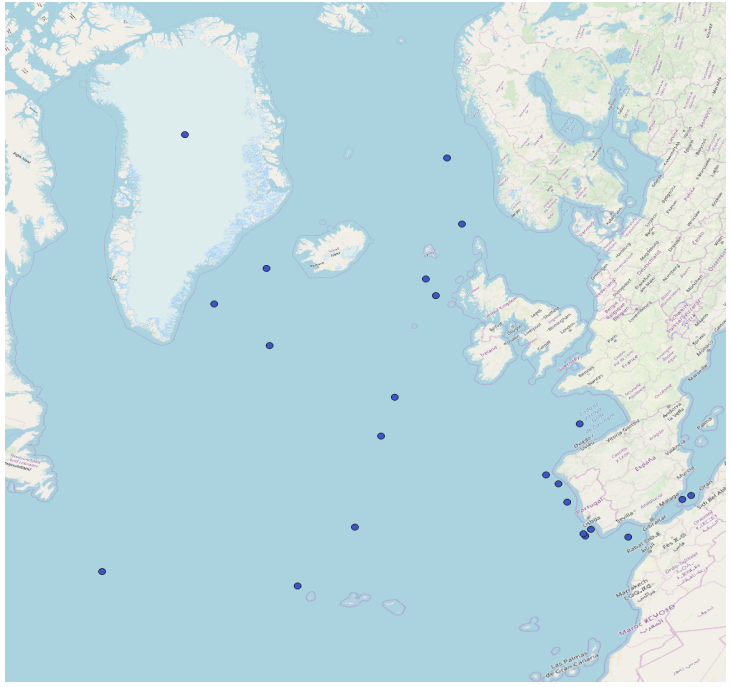
Proxy surrogate reconstructions for Europe and the estimation of their uncertainties

Oliver Bothe and Eduardo Zorita

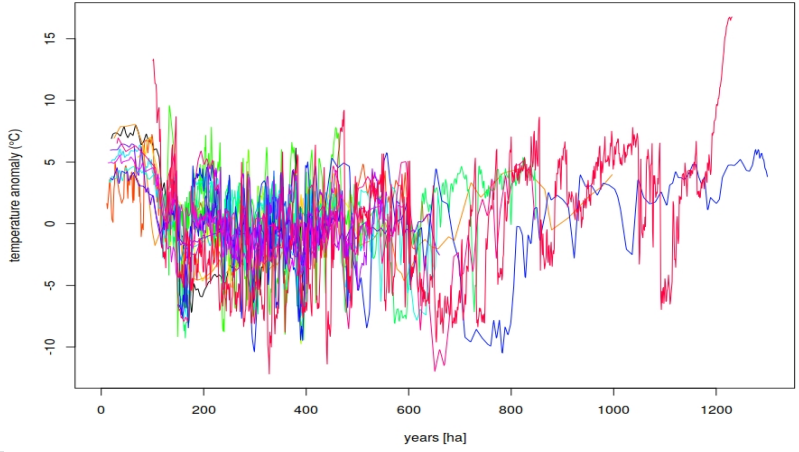
Tropical Pacific – mid-latitude teleconnections in medieval times

Nicholas E. Graham · Malcolm K. Hughes · Caspar M. Ammann · Kim M. Cobb · Martin P. Hoerling · Douglas J. Kennett · James P. Kennett · Bert Rein · Lowell Stott · Peter E. Wigand · Taiyi Xu

Proxy location and record



- 24 proxies (+gisp2) SST and T2m
- Ranging from ~1 -125 ka
- 100 year resolution through interpolation



Current state of the art climate models/simulations

- CMIP6: historical+scenarios 126/245/370/585 2-400 yr/model (daily), 3 models with LGM simulations
- CCSM4-LGM 30 yr (daily) CMIP5
- ERA-interim 39 yr (daily)
- COSMOS 3x glacial+PI ~6k yr (monthly)
- NorESM 115, 120, 125, 127
- Total ~11k potential analogs

Calculating comparable anomalies and analog method

24 proxies P_j with i (1300) time steps

$$RMSE_i = \sqrt{\sum_j (P_j^i - M_j)^2} \quad \forall i \in [t1, t2]$$

This can also be calculated within the anomaly space:

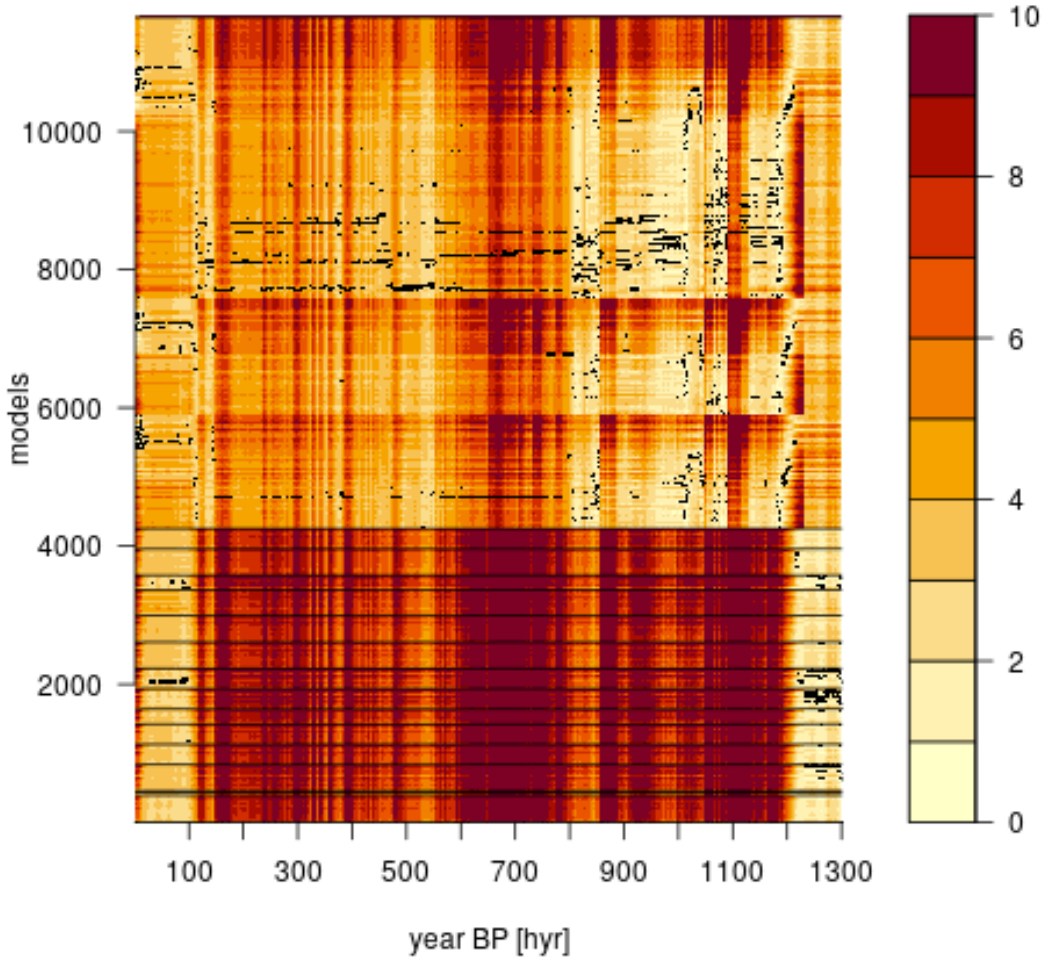
$$RMSE_ik = \sqrt{\sum_j (P_j^i - \overline{P}_j - M_j^{ik} - \overline{M}_j)^2} -> min$$

- Anomalies may be fitting due to large model biases -> linear bias correction

$$RMSE_{ik} = \sqrt{\sum_j (P_j^{i\prime} - [M_j^{ik} - \overline{P}_j + p_{0j} - M_{0j}])^2}$$

with $P_j^{i\prime} = P_j^i - \overline{P}_j$.

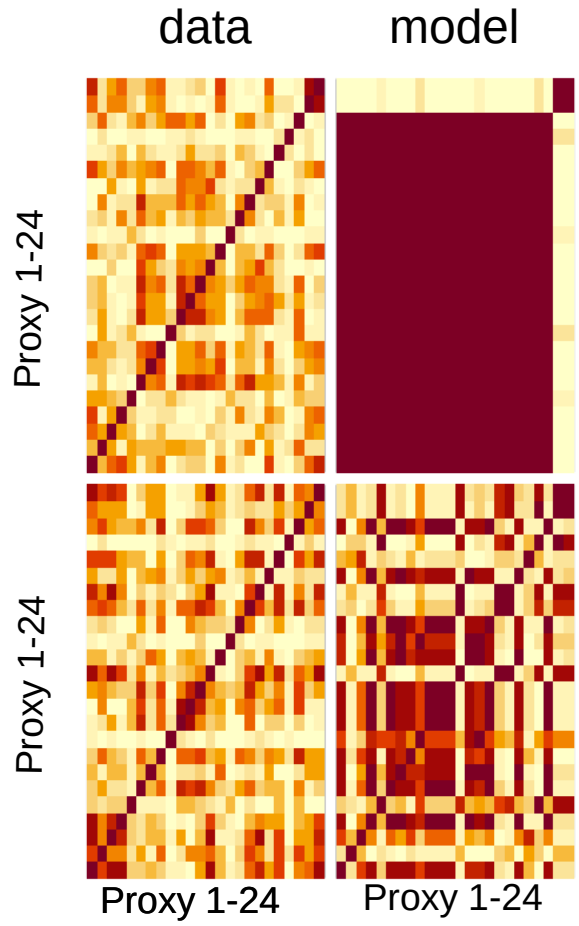
1) Standard deviation normalization?
2) spatial coverage
3) Ice vs marine



- Analog performance decreases during the glacial
  - Much worse for certain time slices
  - Not sufficiently large model pool?
- CMIP 6 projections for the next century are relative good analogs for the Eamian (and vice versa)
- Absolute values cannot be easily compared (as the amount of proxies varies)
- Warm bias in interior of Greenland

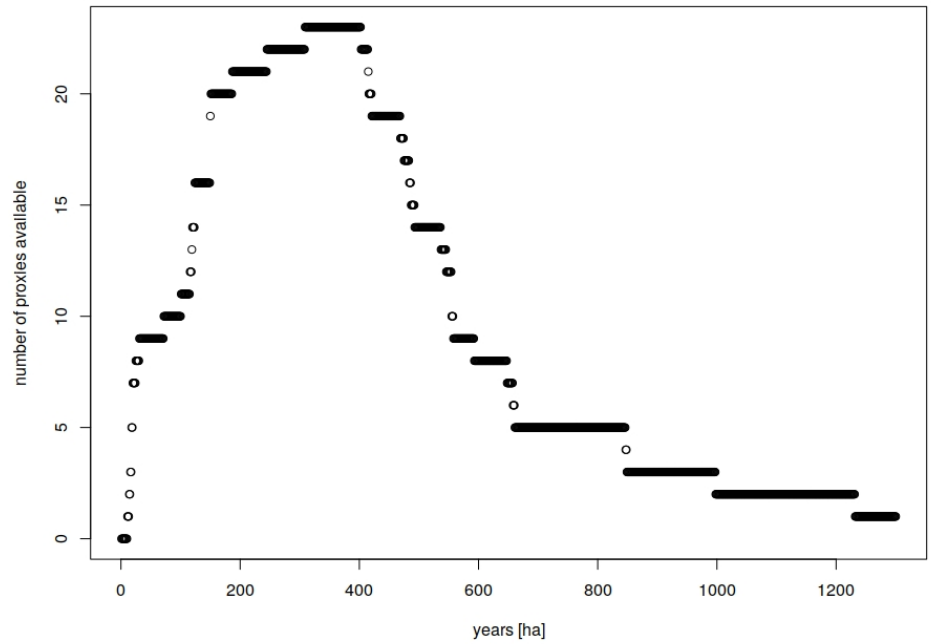
Correlations in the proxy vs the model data

- Different temperature correlations between the proxies and the proxy locations in the model
- Ice cores strongly correlated
- Model due to limited time span higher correlations, and clear patterns visible



Problem missing data – EOF as solution?

- Covariance matrix cannot be calculated in the normal sense, alternative calculations, that can be used in an ensemble set up:
  - Pairwise complete over entire period
  - Observational complete ~350ha-400ha
  - Stepwise pairwise complete



A: 1-100, B: 21-80 and C 11:65

$$\overline{COV} = \begin{bmatrix} A \cdot A/100 & A \cdot B/60 & A \cdot C/55 \\ A \cdot B/60 & B \cdot B/60 & B \cdot C/45 \\ A \cdot C/65 & B \cdot C/45 & C \cdot C/55 \end{bmatrix}$$

Note: COV matrix is not necessary PSD, negative eigenvalues need to be checked

Summary

- Reconstructing the climate of the last glacial cycle based on proxies over the atlantic is doable
  - Multiple degrees of freedom exist:
    - Correlations of the proxy data
    - Differences in the time span of proxy data
    - Spatial oversampling
    - Differences in temporal standard deviation
    - Bias correction of model pool
- Current model pool not sufficiently large
- GCMs may not cover the entire variability of coastal proxies even on centennial time scales

EOFs as solution

- Advantages
  - Spatial correlations accounted for
  - High frequency noise removed
- Disadvantages
  - Missing value treatment difficult
  - Temporal in-homogeneity

$$X = \begin{bmatrix} P_1^1 & P_1^2 & .. & P_1^n \\ P_2^1 & .. & .. & P_2^n \\ .. & .. & .. & .. \\ P_m^1 & P_m^2 & .. & P_m^n \end{bmatrix}$$

$$X' = \begin{bmatrix} P_1^{1\prime} & P_1^{2\prime} & .. & P_1^{n\prime} \\ P_2^{1\prime} & .. & .. & P_2^{n\prime} \\ .. & .. & .. & .. \\ P_m^{1\prime} & P_m^{2\prime} & .. & P_m^{n\prime} \end{bmatrix} = \begin{bmatrix} P_1^1 - \overline{P}_1 & P_1^2 - \overline{P}_1 & .. & P_1^n - \overline{P}_1 \\ P_2^1 - \overline{P}_2 & .. & .. & P_2^n - \overline{P}_2 \\ .. & .. & .. & .. \\ P_m^1 - \overline{P}_m & P_m^2 - \overline{P}_m & .. & P_m^n - \overline{P}_m \end{bmatrix}$$

$$RMSE_{ik} = |X^{i\prime} - M^{ik} - \overline{X} + X_0 - M_0| = |X^{i\prime} - M^{ik\prime}|$$

$$COV \cdot EOFs = \Lambda EOFs$$

$$RMSE_{ik} = |EOFs^T \cdot X^{i\prime} - EOFs^T \cdot M^{ik} - EOFs^T \cdot \overline{X} + EOFs^T \cdot X_0 - EOFs^T \cdot M_0| = |EOFs^T \cdot X^{i\prime} - EOFs^T \cdot M^{ik\prime}|$$

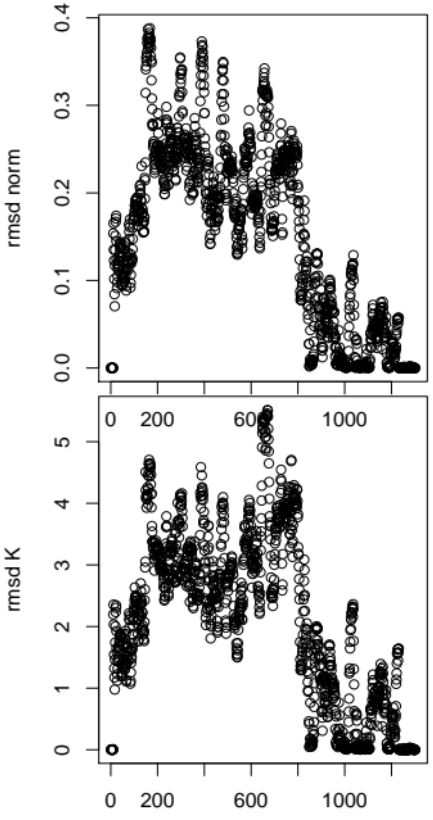
The columns of X and X' are the measurements at a single timestep. We will denote them $X^i/X^{i\prime}$ for future discussion.

BJERKNES CENTRE for Climate Research

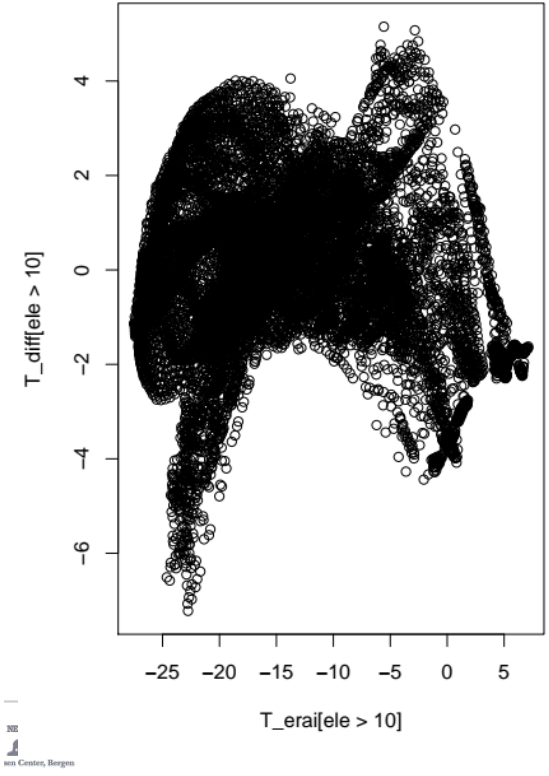
BERGENS FORSKNINGS STIFTELSE

How to bias correct?

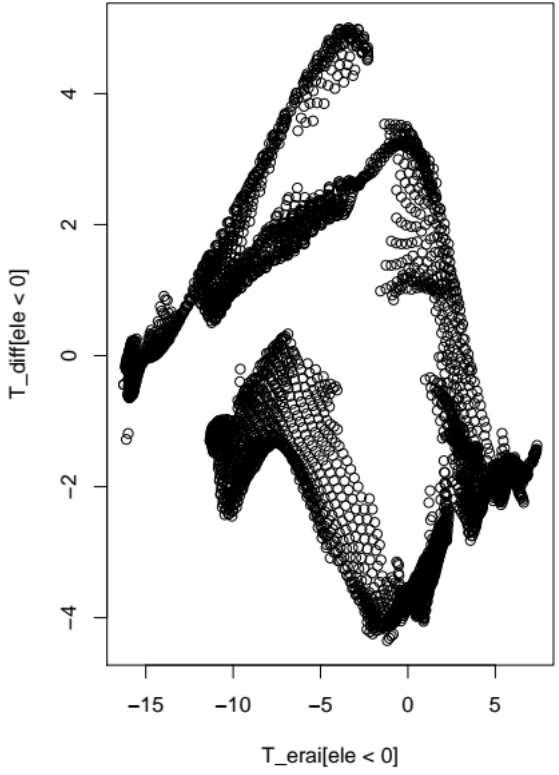
Ice core+10°

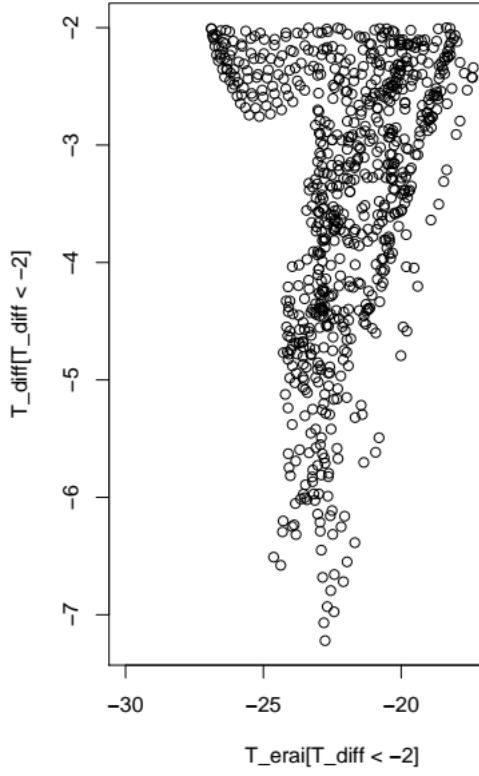


Land

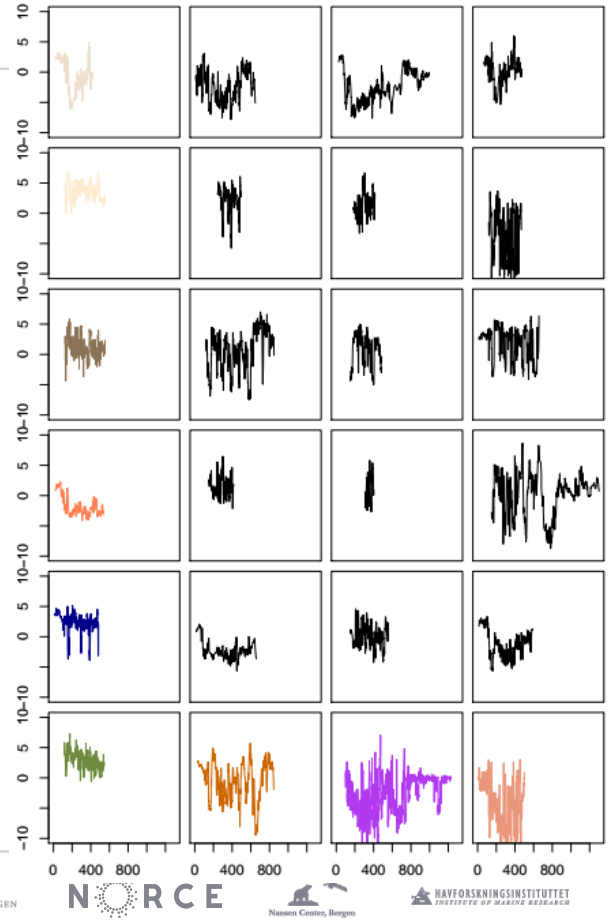


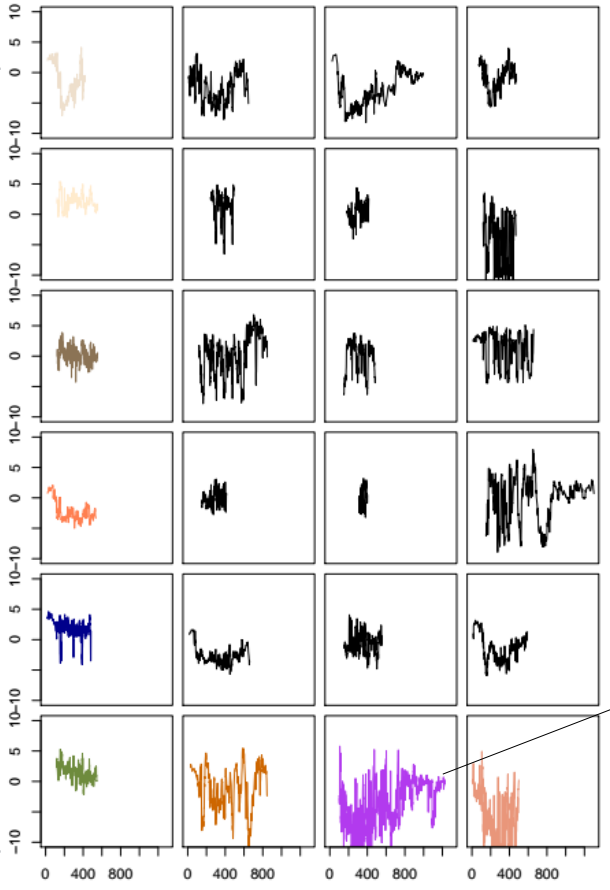
water





Best analog performance at proxy location





Normalized worse at ice core