Rates of Change in Past Warm Periods, Part 1

Manfred Mudelsee,

Institute of Geosciences, University Potsdam, Germany

Climate Risk Analysis, Germany

Dear colleague,

my apologies for being unable to come to Vienna and present this poster. This is the title page. The full PDF, available as Supplementary Material at the EGU site and also at https://www.manfredmudelsee.com/publ/pdf/mudelsee-egu-2024.pdf*, has the content plus links to videos and online chat on Friday 10:45 to 12:30. MM.*

SPP 2299

Funded by DFG Deutsche Forschungsgemeinschaft German Research Foundation

Funded by the European Union

Abstract

Since the publication of the IPCC's Fifth Assessment Report in 2013, there has been increasing evidence that the social and ecological impacts of global warming depend more on seasonal extremes (e.g. peak summer temperatures) than on trends in annual averages. This is particularly true in the tropics, where extremes have become the greatest threat to ecosystems. However, little is known about the current and future rates of change in means and extremes. Lack of high-resolution data from past warm climates (which serve as analogues) and lack of advanced data analysis methods explain this knowledge deficit.

The SEARCH project (Seasonal Extremes and Rates of Change in Past Warm Climates: Insights from Advanced Statistical Estimations on High-Resolution Coral Proxy Records) aims to advance our knowledge by means of (1) using a database of high-resolution coral proxy records and (2) applying advanced simulation techniques from statistical science. SEARCH uses a database of about 50 existing and new (bi-)monthly resolved coral proxy records during the (a) Anthropocene, (b) Medieval Climate Anomaly-Medieval Warm Period, (c) Holocene Thermal Maximum, (d) Last Interglacial and (e) Mid-Pliocene Warm Period.

In the first part of our presentation series, we explain the methodological foundations (Mudelsee 2014, 2023): proxy calibration, nonparametric kernel estimation of the first derivative of the climate proxy series and linear regression. The methods take into account typical peculiarities of paleoclimate time series: non-Gaussian distributions, autocorrelation, uneven spacing and uncertain timescales. We present some initial results. Based on the (preliminary) results of SEARCH, we also consider the lessons for navigating the climate future within the framework of the GreenSCENT project (Smart Citizen Education for a Green Future).

Acknowledgements:

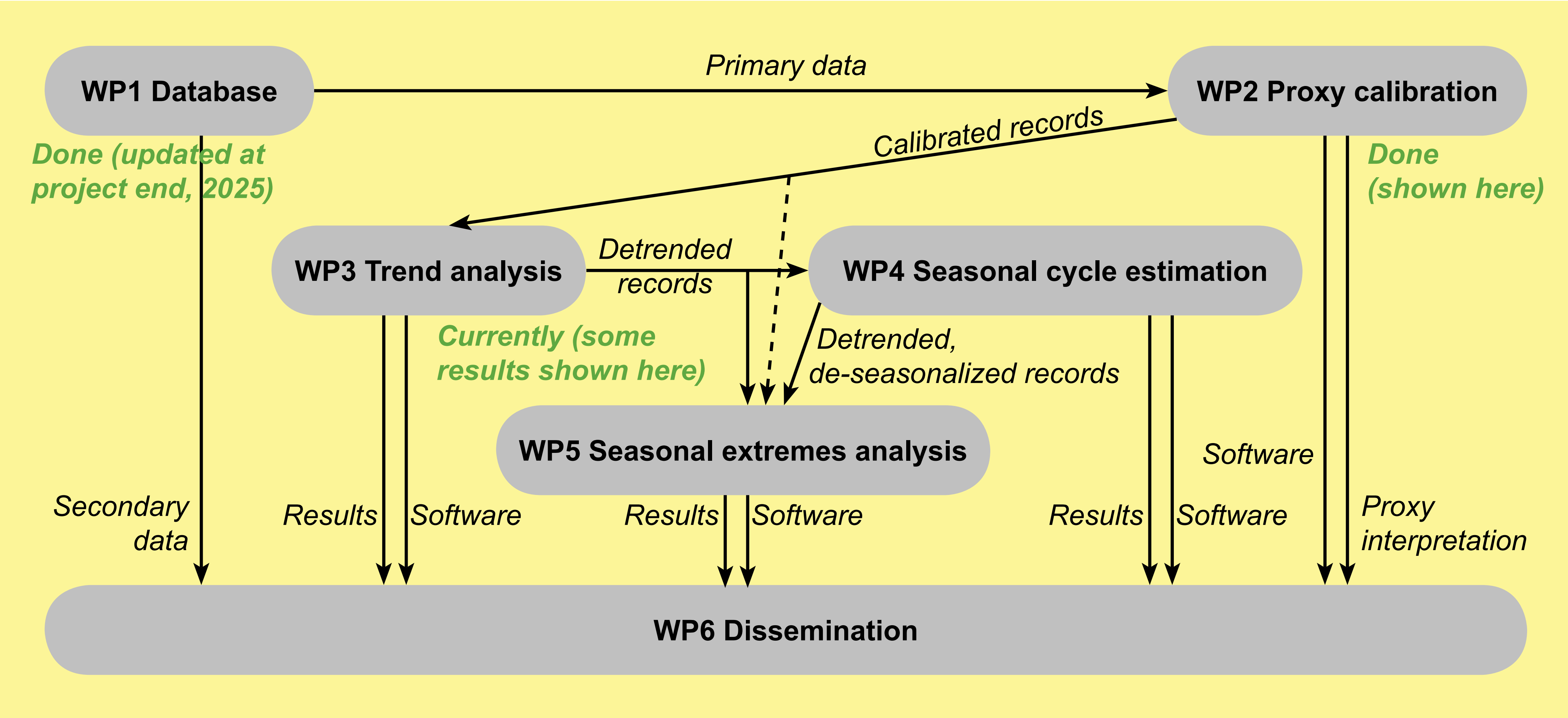
This work has been funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation), project number 468589022 (SEARCH), within the SPP 2299, project number 441832482; and by the European Union’s Horizon 2020 research and innovation programme under grant agreement No 101036480 (GreenSCENT).

References:

Mudelsee M (2014) Climate Time Series Analysis: Classical Statistical and Bootstrap Methods. Second Edition. Springer, Cham. xxxii + 454 pp [https://www.manfredmudelsee.com/book/index.htm]

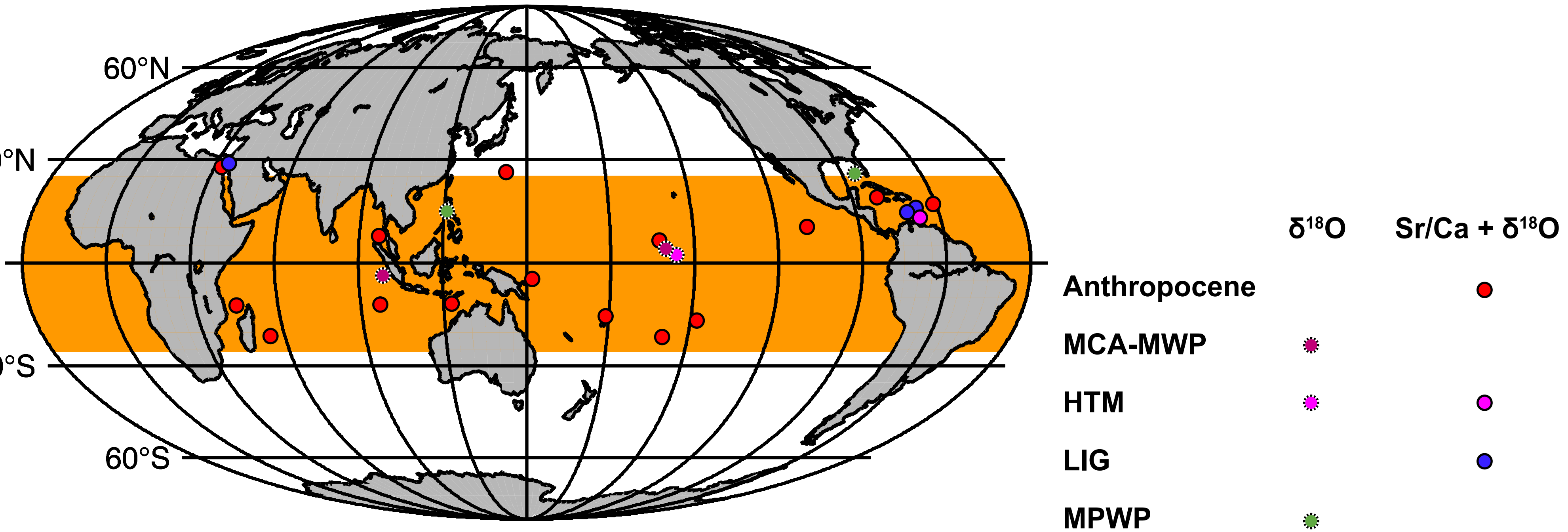
Mudelsee M (2023) Unbiased proxy calibration. Mathematical Geosciences. (doi:10.1007/s11004-023-10122-5).

Structure and Status



WP1: Database

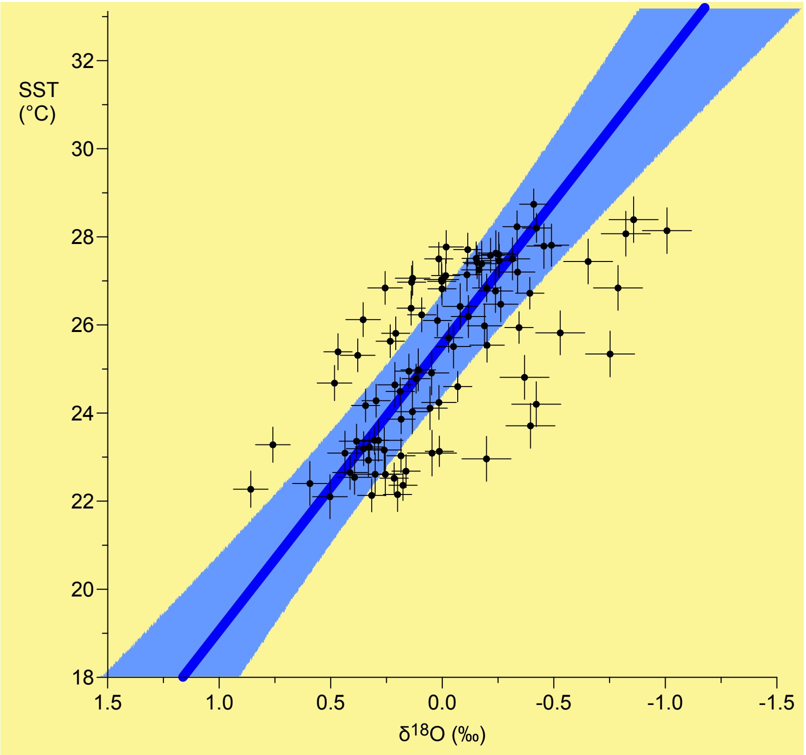
Currently 47 records



Anthropocene,	MCA–MWP,	HTM,	LIG,	MPWP
since ~1610	AD 1146–1465	4–6 ka	118–124 ka	3–3.7 Ma

MCA–MWP, Medieval Climate Anomaly–Medieval Warm Period;
HTM, Holocene Thermal Maximum; LIG, Last Interglacial; MPWP, Mid-Pliocene Warm Period

WP2: Proxy Calibration



Correct technique

Y, response variable

SST

X, predictor variable

coral $\delta^{18}O$

estimation via

WLSXY or OLSBC

(i.e., bias correction)

Explanation: predictor noise

Mudelsee (2023) *Math Geosci* (doi:10.1007/s11004-023-10122-5)

WP2: Proxy Calibration

1.	Bivariate time series	$\left\{t(i), x(i), y(i)\right\}_{i=1}^{n}$
2.	Parameter estimates from OLSBC or WLSXY	$\widehat{\beta}_0, \widehat{\beta}_1$
3.	Residuals	$e_X(i), e_Y(i)$
4.	Fit values	$x_{\text{fit}}(i) = x(i) - e_X(i)$, $y_{\text{fit}}(i) = y(i) - e_Y(i)$
5.	Bias-correcte AR(1) parameters estimated on residuals, block length selection	$\widehat{\bar{a}}'_X, \widehat{\bar{a}}'_Y$; l
6.	Resampled residuals, pairwise-MBB with l	$\left\{e_X^{*b}(i), e_Y^{*b}(i)\right\}_{i=1}^{n}$ (b, counter)
7.	Resample	$x^{*b}(i) = x_{\text{fit}}(i) + e_X^{*b}(i)$, $y^{*b}(i) = y_{\text{fit}}(i) + e_Y^{*b}(i), i = 1, \ldots, n$
8.	Replication, parameters	$\widehat{\beta}_0^{*b}, \widehat{\beta}_1^{*b}$
9.	Replication, prediction	$\widehat{y}^{*b}(n+1) = \widehat{\beta}_0^{*b} + \widehat{\beta}_1^{*b} \cdot \left[x(n+1) + S_X \cdot \mathcal{E}_{\text{N}(0,\,1)}(n+1)\right]$
10.	Go to step 6 until $b = B = 2,000$ replications exist each	$\left\{\widehat{\beta}_0^{*b}\right\}_{b=1}^{B}, \left\{\widehat{\beta}_1^{*b}\right\}_{b=1}^{B}, \left\{\widehat{y}^{*b}(n+1)\right\}_{b=1}^{B}$
11.	Calculate CI on the basis of replications	

Complete description of prediction error

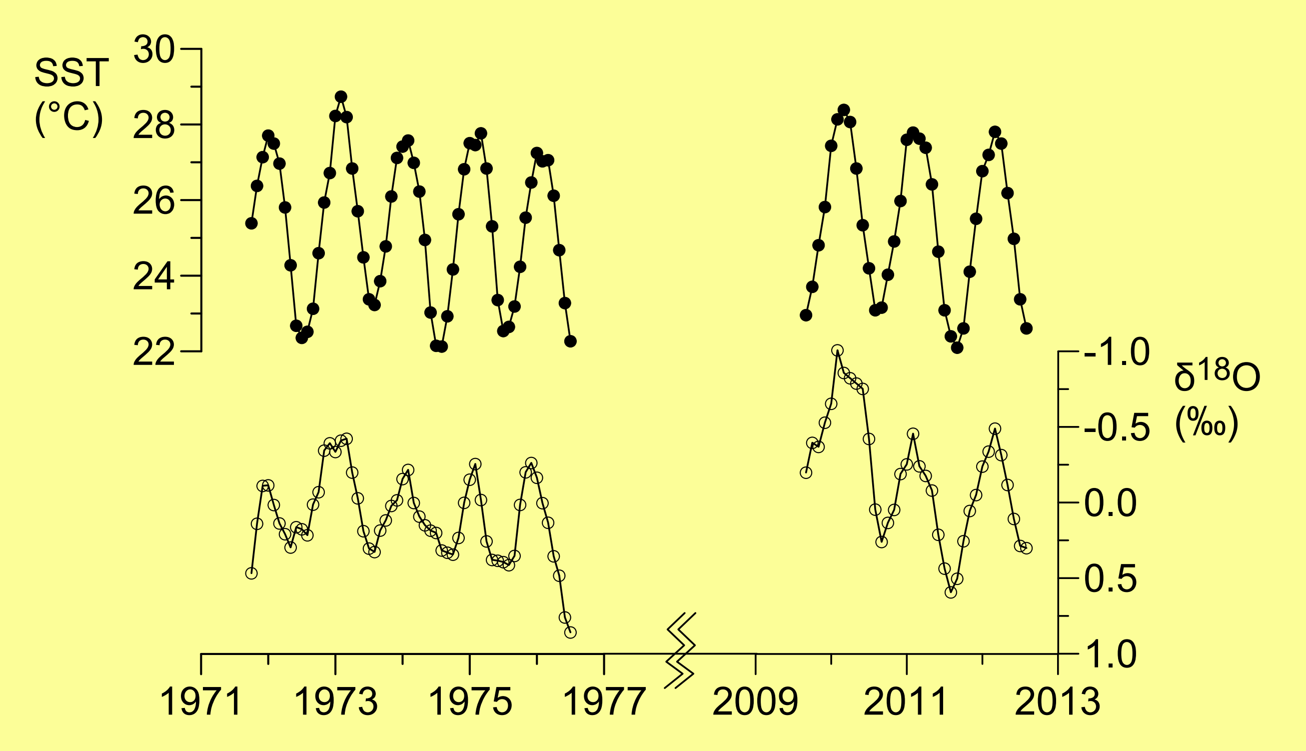
Observation $x(n+1)$

Standard error, S_X

Gaussian assumption

Mudelsee (2023) *Math Geosci* (doi:10.1007/s11004-023-10122-5)

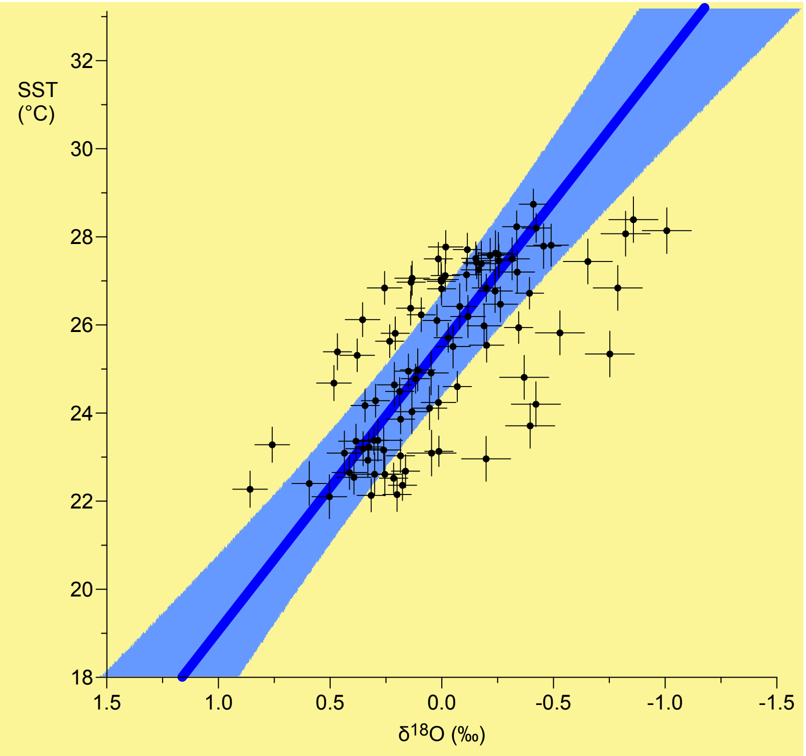
WP2: Proxy Calibration



Mudelsee (2023) *Math Geosci* (doi:10.1007/s11004-023-10122-5)

Brenner et al. (2017) *Paleoceanography* 32:182 (doi:10.1002/2016PA002973)

WP2: Proxy Calibration



WLSXY $s_X(n + 1) = 0.11$ ‰

$\hat{\beta}_1 = -6.5$ °C/‰ [−8.0 °C/‰; −5.0 °C/‰]

$n = 94$, $\bar{d} = 0.4$ a

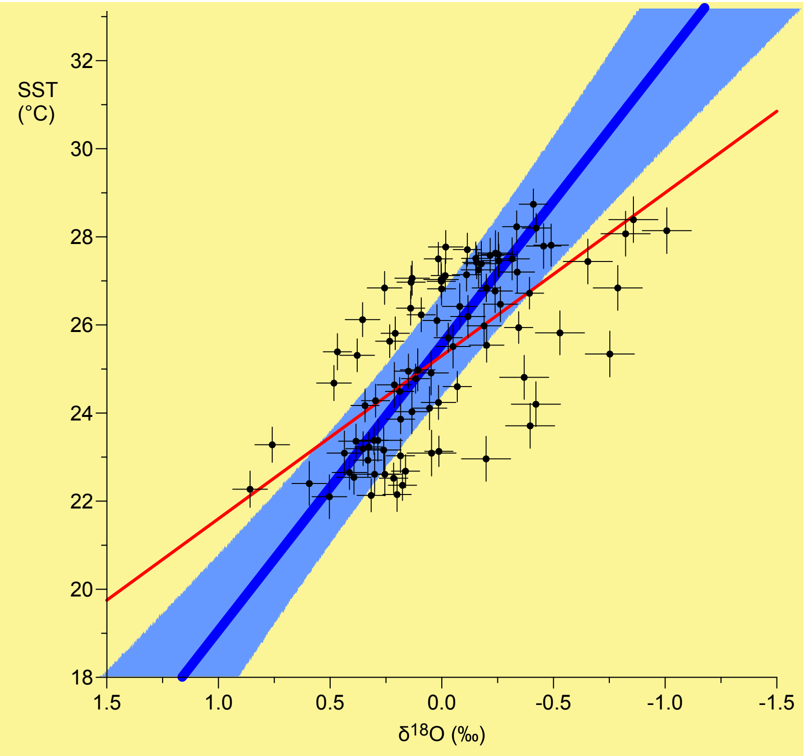
$\hat{\tau}'_X = 0.9$ a, $\hat{\bar{a}}'_X = 0.64$

$\hat{\tau}'_Y = 1.2$ a, $\hat{\bar{a}}'_Y = 0.72$

$l = 9$,* $B = 2000$, $\alpha = 0.025$

Mudelsee (2023) *Math Geosci* (doi:10.1007/s11004-023-10122-5)
Brenner et al. (2017) *Paleoceanography* 32:182 (doi:10.1002/2016PA002973)

WP2: Proxy Calibration



WLSXY $s_X(n+1) = 0.11$ ‰

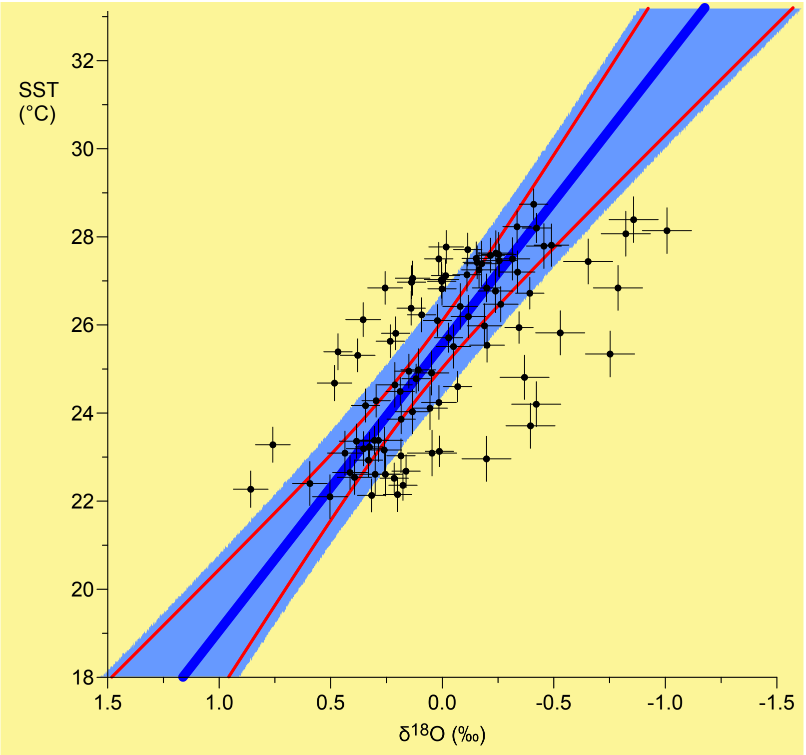
$\hat{\beta}_1 = -6.5$ °C/‰ [−8.0 °C/‰; −5.0 °C/‰]

OLS

$\hat{\beta}_1 = -3.7$ °C/‰

Mudelsee (2023) *Math Geosci* (doi:10.1007/s11004-023-10122-5)
Brenner et al. (2017) *Paleoceanography* 32:182 (doi:10.1002/2016PA002973)

WP2: Proxy Calibration

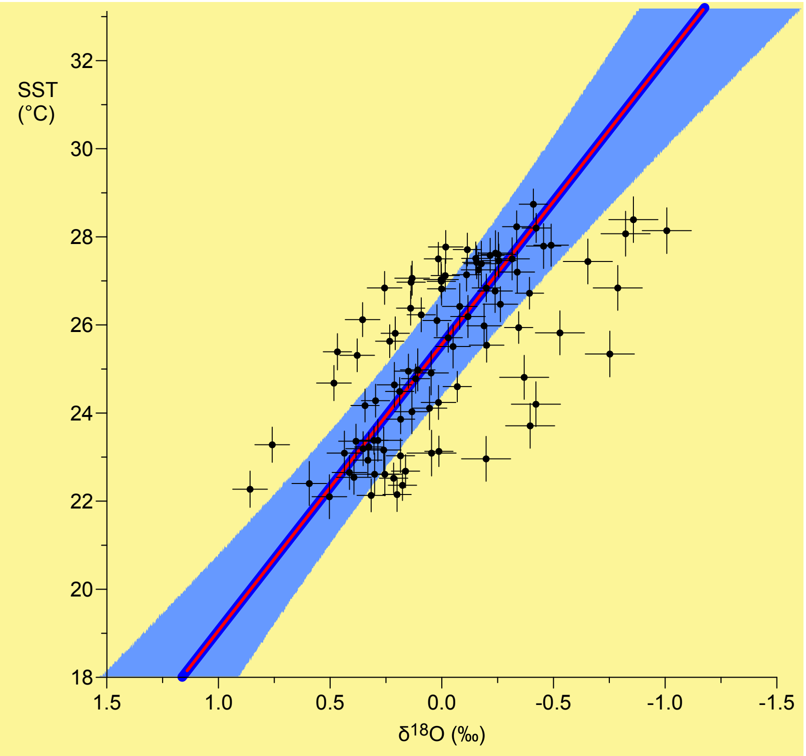


WLSXY $s_X(n+1) = 0.11$ ‰ $s_X(n+1) = 0$ ‰

$\hat{\beta}_1 = -6.5$ °C/‰ [−8.0 °C/‰; −5.0 °C/‰]

Mudelsee (2023) *Math Geosci* (doi:10.1007/s11004-023-10122-5)
Brenner et al. (2017) *Paleoceanography* 32:182 (doi:10.1002/2016PA002973)

WP2: Proxy Calibration



WLSXY $s_X(n + 1) = 0.11$ ‰

$\hat{\beta}_1 = -6.5$ °C/‰ [–8.0 °C/‰; –5.0 °C/‰]

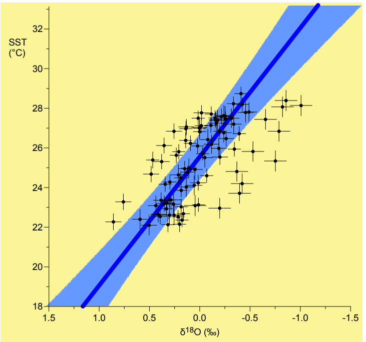
WLSXY with X and Y switched

$\hat{\beta}_1 = -6.5$ °C/‰

Mudelsee (2023) *Math Geosci* (doi:10.1007/s11004-023-10122-5)

Brenner et al. (2017) *Paleoceanography* 32:182 (doi:10.1002/2016PA002973)

WP2: Proxy Calibration



Explanatory video modules

from commercial course

Climate Time Series Analysis

free access until 21 April 2024

Module 14: Regression II, Lecture

https://start.video-stream-hosting.de/player.html?serverip=116.202.148.2&serverapp=climateriskanalysis-vod&streamname=course/EGU-2024-avqtz5e623bcu3uig5f4890j849jh/Module-14-Regression-II-Chapter-8-Lecture.smil

Module 15: Regression II, Tutorial

https://start.video-stream-hosting.de/player.html?serverip=116.202.148.2&serverapp=climateriskanalysis-vod&streamname=course/EGU-2024-avqtz5e623bcu3uig5f4890j849jh/Module-15-Regression-II-Chapter-8-Tutorial.smil

Current course (3 to 7 June 2024):

https://www.climate-risk-analysis.com/courses/time-series/49th-Online-Course-in-Climate-Time-Series-Analysis.html

Mudelsee (2023) *Math Geosci* (doi:10.1007/s11004-023-10122-5)

WP3: Trend Analysis

Estimation target: slope

Estimation models

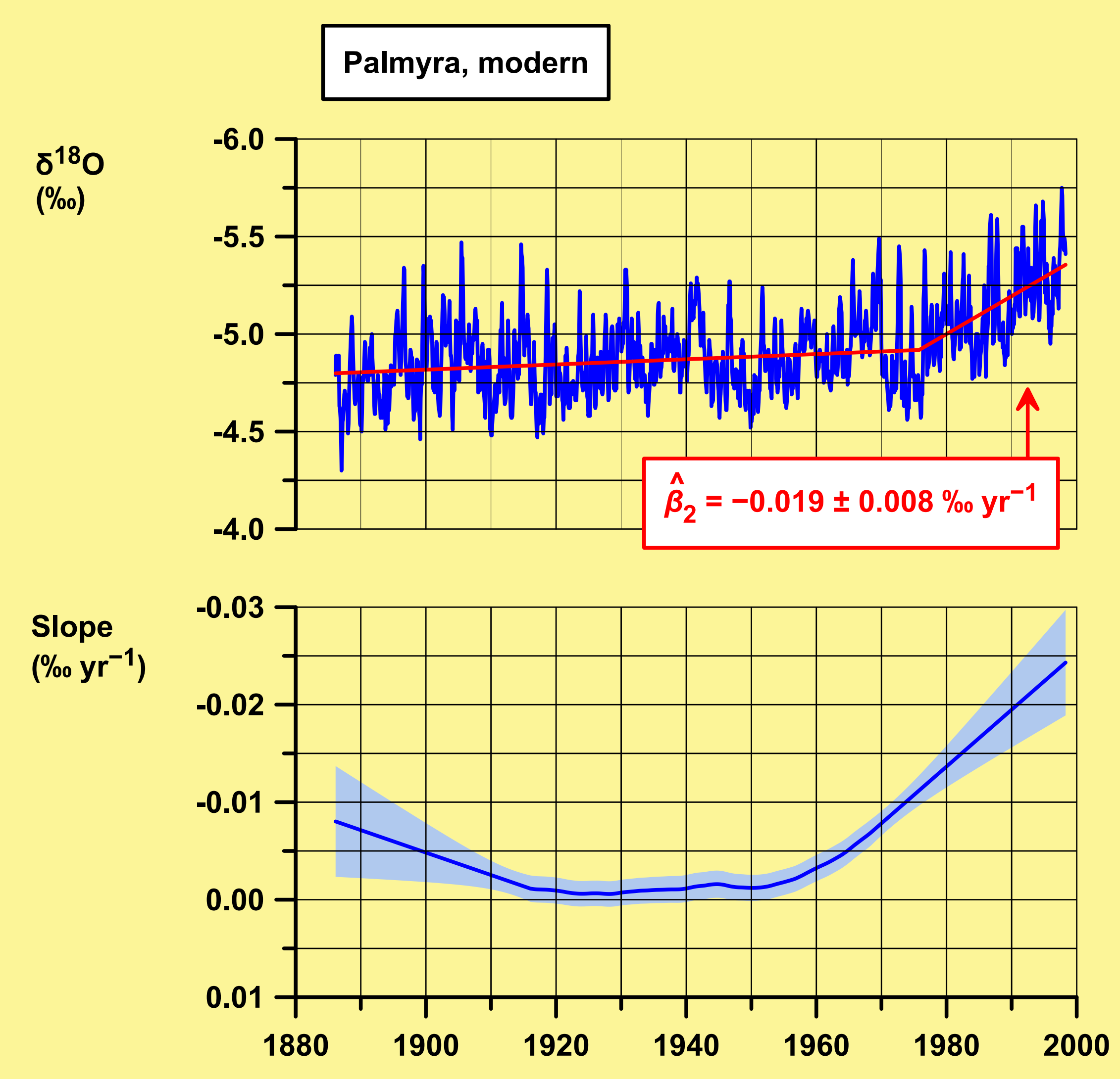
- piece-wise linear, ordinary least squares
- nonparametric, Gasser–Müller kernel smoothing

Estimation standard errors (1-σ sigma level, ± symbol)

- moving-block bootstrap resampling
- 2000 resamples

Mudelsee (2014) *Climate Time Series Analysis.* 2nd edition, Springer, 454 pp. [Chapter 4]

WP3: Trend Analysis



Break point

$\hat{t}_2 = 1976 \pm 6$

$\hat{x}_2 = -4.92 \pm 0.04$ ‰

Right slope (warming)

$\hat{\beta}_2 = -0.019 \pm 0.008$ ‰ yr^{-1}

Kernel bandwidth 30 yr

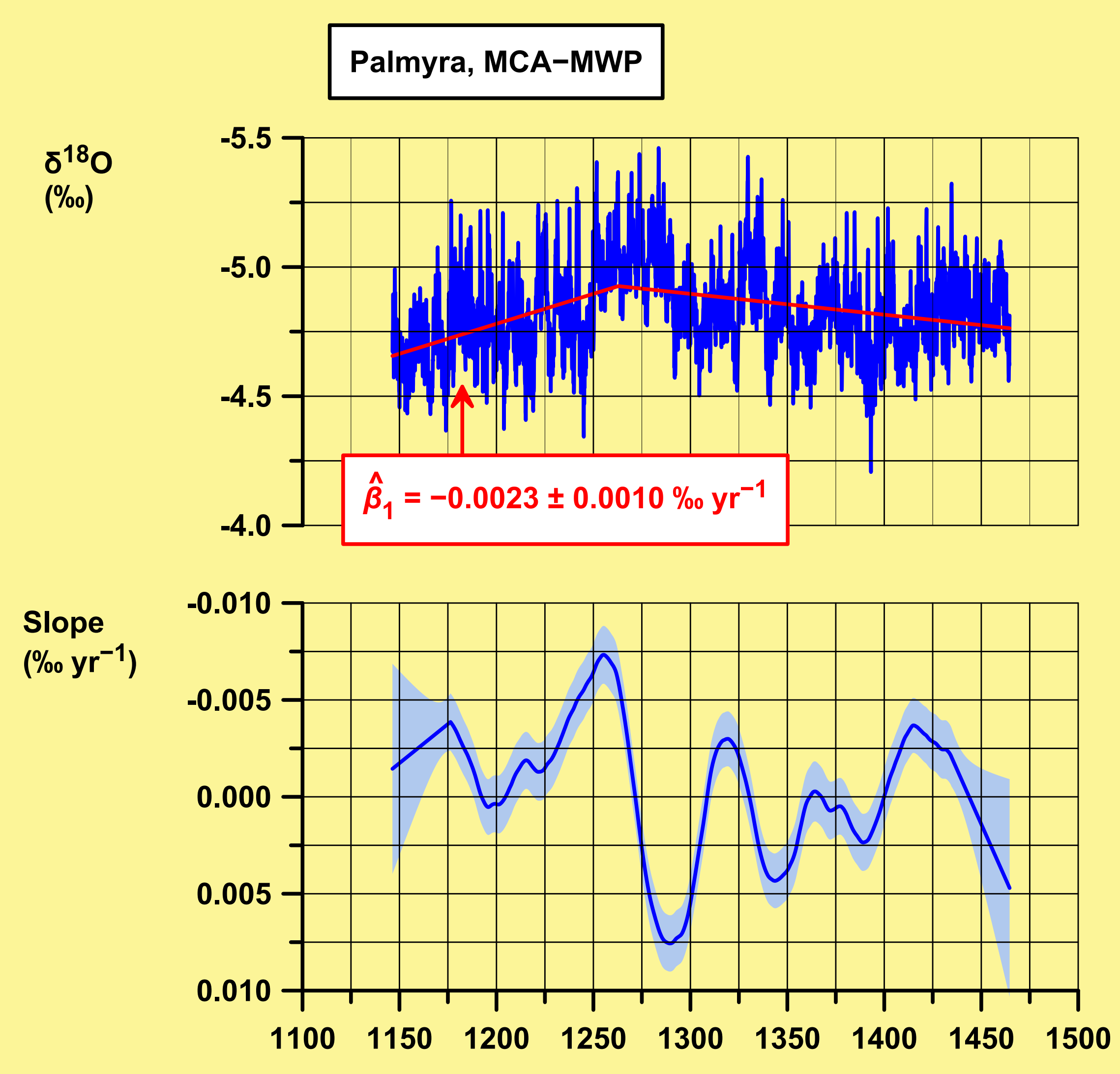
Slope estimate

standard-error band

Cobb et al. (2001) *Geophys Res Lett* 28:2209 (doi:10.1029/2001GL012919)

Nurhati et al. (2011) *J Climate* 24:3294 (doi:10.1175/2011JCLI3852.1)

WP3: Trend Analysis



Break point

$\hat{t}_2 = 1263 \pm 2$

$\hat{x}_2 = -4.93 \pm 0.03$ ‰

Left slope (warming)

$\hat{\beta}_1 = -0.0023 \pm 0.0010$ ‰ yr^{-1}

Kernel bandwidth 30 yr

Slope estimate

standard-error band

Cobb et al. (2001) *Geophys Res Lett* 28:2209 (doi:10.1029/2001GL012919)

Nurhati et al. (2011) *J Climate* 24:3294 (doi:10.1175/2011JCLI3852.1)

Conclusions and Outlook

Modern warming unprecedented?*

- too early for making firm conclusions
  - since to be done:
    - proxy calibration error propagation
    - sensitivity analyses for
      - kernel bandwidth
      - fit interval
    - analysis of further more datasets

* Note recent EU-funded project GreenSCENT on the European Green Deal

Rates of Change in Past Warm Periods, Part 1

Manfred Mudelsee,

Institute of Geosciences, University Potsdam, Germany

Climate Risk Analysis, Germany

Thanks for your attention!

I am available for an online chat during

poster attendance time (Friday 10:45 to 12:30) at

https://climateriskanalysismanfredmudelseeek.my.webex.com/climateriskanalysismanfredmudelseeek.my/j.php?MTID=m54a928e3022e15b0625ea91e6540cea0

MM

SPP 2299

Funded by DFG Deutsche Forschungsgemeinschaft German Research Foundation

Funded by the European Union