https://doi.org/10.5194/essd-2025-599
Preprint. Discussion started: 9 October 2025

Open Access Earth System Science Data Discussions

The PALMOD 130k marine palaeoclimate data synthesis version 2

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Abstract

Palaeoclimate data hold the unique promise of providing a long-term perspective on climate change and as such can serve as an important benchmark for climate models. However, palaeoclimate data have generally been archived with insufficient standardisation and metadata to allow for transparent and consistent uncertainty assessment in an automated way. Thanks to improved computation capacity, transient palaeoclimate simulations are now possible, calling for data products containing multi-parameter time series rather than information on a single parameter for a single time slice. To confront transient simulations that span the last glacial-interglacial cycle with palaeoclimate data, we have compiled a multi-parameter marine palaeoclimate data synthesis that contains time series spanning 0 to 130,000 years ago. In 2020 Jonkers et al. (2020) published the first version of the PALMOD 130k marine palaeoclimate data synthesis and described our data synthesis strategy and the contents and format of the data product in detail. Here we present a major update of the data product that markedly increases both the spatial and temporal coverage. Version 2 of the synthesis contains 2,286 time series of eight palaeoclimate parameters from 475 individual sites, each associated with rich metadata, age–depth model ensembles, and information to refine and update the chronologies. Version 2 contains 468 time series of benthic foraminifera $\delta^{18}O$; 357 of benthic foraminifera $\delta^{13}C$; 423 of near sea surface temperature; 482 and 273 of planktonic foraminifera $\delta^{18}O$ and $\delta^{13}C$; and 128, 111 and 44 of carbonate, organic carbon and biogenic silica content, respectively. Compared to version 1, all radiocarbon ages have been recalibrated and the age-depth models updated. In addition, near sea surface temperature estimates based on planktonic

https://doi.org/10.5194/essd-2025-599
Preprint. Discussion started: 9 October 2025

foraminifera Mg/Ca and on UK37' have been recalculated using a single calibration thus ensuring global comparability and comprehensive assessment of their uncertainty. The data product is available in two formats (R and LiPD) facilitating use across different software and operating systems and can be downloaded at https://doi.pangaea.de/10.1594/PANGAEA.984602 (Jonkers et al., 2025b). This data descriptor presents our updating methodology and describes the contents and format of the data product in detail and concludes with recommendations on palaeodata stewardship to increase the reusability of such data.

1 Introduction

This article describes an update of the PALMOD 130k multiproxy marine palaeoclimate data synthesis (Jonkers et al., 2020). Palaeoclimate data hold the unique promise to inform about climate states and climate variability on time scales beyond the instrumental period. As such, they may help to characterise natural climate variability, shed light on the mechanisms of climate change and provide analogues for future climate; all crucial insights in a rapidly changing world. Marine sediments and the compounds and fossils contained in them allow the reconstructions of largely continuous, long records of past ocean physical and chemical conditions. Consequently, the multiproxy, global-scale PALMOD 130k synthesis provides a basis to evaluate the importance of the ocean for regulating Earth's climate and biogeochemical cycles on a global scale.

The synthesis contains palaeoceanographic and sedimentological data from sediment cores that cover the last glacial–interglacial cycle (up to approximately 130,000 years ago). During this time Earth has undergone marked changes in climate that involve the atmosphere, continental ice sheets and the ocean (Jonkers et al., 2023; NGRIP Members, 2004; Waelbroeck et al., 2002). Up to the influence of humans on global climate, which accelerated around 1950 CE (Steffen et al., 2015), these changes were ultimately controlled by variations in the Earth's orbit around the Sun (Hays et al., 1976). This orbital forcing triggered a multitude of (non-linear) feedback mechanisms causing global and regional climate to vary much faster than the forcing. A large amount of palaeoclimate data that span this period has been collected over the past decades, rendering the last glacial–interglacial cycle well-suited to study the natural variability of ocean and climate conditions across timescales and in particular the interaction between the cryosphere and the rest of the climate system. This is especially relevant given the projected,

https://doi.org/10.5194/essd-2025-599
Preprint. Discussion started: 9 October 2025

but uncertain, (partial) disappearance of continental ice-sheets with ongoing anthropogenic warming. The high-density data availability also makes the period an excellent test-bed for climate model simulations.

Whilst for a long time, palaeoclimate modelling focussed on the simulation of timeslices, increasing computational power now also enables long transient simulations. For instance, the paleoclimate modelling intercomparison project (PMIP) now also provides protocols for the simulation of the last deglaciation (Ivanovic et al., 2016) and several simulations spanning this period exist (Liu et al., 2009; Mikolajewicz et al., 2025). This development allows investigating climate dynamics in a new way, but also puts new demands on the (palaeo)observational data needed for model benchmarking. Specifically, paleoclimate time series need to be associated with comprehensive and consistent estimates of their (chronological) uncertainty. Moreover, the stochastic aspects of climate also call for new ways of comparing transient simulations with observations. For instance, given the uncertainty about whether suborbital abrupt climate variability is forced or unforced, the observed temporal evolution of climate may represent just one of many possible trajectories. Therefore, data-model comparison strategies that are independent of the exact timing of events need to be considered (Weitzel et al., 2024).

A particular strength of paleoceanographic data is that by their multiproxy nature. We can hence gain a more comprehensive insight into the climate system by studying it from a multi-proxy, or multi-parameter, perspective. Moreover, a multi-parameter approach is also likely to be more diagnostic for model performance than a single climate parameter approach (Kurahashi-Nakamura et al., 2017). However, at present, multi-parameter approaches are difficult because different parameters from the same archive (sediment core) have often been generated in different studies, and the current poor state of data archiving poses serious challenges to reuse. These challenges arise mainly from the non-standardised and fragmented way palaeoceanographic data (and palaeoclimate data in general) are archived and the scarcity of machine-readable metadata directly included in datafiles. Automated and reproducible analyses of palaeoceanographic data thus remain time consuming, even though efforts are underway to alleviate these problems and increase the ease of data reuse (Emile-Geay and Eshleman, 2013; Morrill et al., 2021). Still, such approaches require standardisation and synthesis of raw and inferred data and of metadata from various sources.

The PALMOD 130k marine palaeoclimate data synthesis is an attempt to overcome the fragmented nature of paleoceanographic data sets and contains multiple climate-relevant parameters in a single framework. The synthesis combines data on sediment composition

https://doi.org/10.5194/essd-2025-599
Preprint. Discussion started: 9 October 2025

(carbonate content, total organic carbon and opal), planktonic and benthic foraminifera stable oxygen and carbon isotope ratios and estimates of seawater temperature based on various proxies. All data has been compiled on a single depth scale per sediment core allowing for robust alignment of the various parameters and for reproducible updating and changing of chronologies. Whenever possible, the synthesis contains raw observational data together with the inferred data to enable revision of the latter. All data is associated with rich metadata to facilitate interpretation and for comprehensive uncertainty estimates. The synthesis is designed to facilitate evaluation of transient climate model simulations, but the data product can also be used to study climate change over the last glacial–interglacial cycle directly, independent from climate model simulations. Whilst the intended use of the synthesis has remained unchanged, version 1 was limited in spatial and temporal coverage, thus warranting an update to increase its usefulness. This article describes this update of the data synthesis and complements an earlier description of the data product (Jonkers et al., 2020).

2 What's new

Briefly, version 2 of the PALMOD 130k marine palaeoclimate data synthesis contains 1736 additional time series from 332 individual sites, markedly increasing both the spatial and temporal coverage of the data. Next, age-depth models presented in version 1 that were based on radiocarbon ages are revised using calendar ages calculated with the updated radiocarbon calibration curve. In addition, we harmonised seawater temperature estimates based on geochemical proxies and provide uncertainty estimates that are consistent and comparable across the different time series. This version also corrects several errors in the metadata associated with time series included in version 1 and contains two additional metadata fields to facilitate filtering of the data. Finally, we made slight changes in the structure of the data to prevent errors during use.

3 Methods

3.1 Data synthesis strategy

The synthesis strategy of this version follows that of the previous version (Jonkers et al., 2020). We compiled time series from marine sediment cores that contained benthic or planktonic

https://doi.org/10.5194/essd-2025-599
Preprint. Discussion started: 9 October 2025

foraminifera stable oxygen and carbon isotope data, estimates of seawater temperature and information on total organic carbon, opal and carbonate content. As outlined in Jonkers (2020), we followed a sequential updating strategy guided by the availability of time series with information needed to develop an age depth model for the sediment cores of interest. Version 1 contained time series dated with radiocarbon and benthic foraminifera $\delta^{18}O$. Version 2 integrates two steps in the update process, it contains time series with any of the parameters of interest with age control solely based on benthic foraminifera $\delta^{18}O$ and it contains time series that had at least an estimate of seawater temperature and age control based on radiocarbon or other absolute dates. Data was compiled from public repositories following the two-step approach of bulk data download and subsequent filtering out of relevant time series as described in Jonkers (2020). To increase the number of time series from the Indo-Pacific domain we made 19 previously unpublished datasets available on PANGAEA and included them here. Given the lack of metadata associated with most data in public repositories, metadata was in general manually compiled from the publications associated with the datasets.

3.2 Age-depth modelling

All time series in this compilation have updated and harmonised age-depth models with consistent estimates of their uncertainty. The updated age-depth models are based on the most recent regional benthic foraminifera $\delta^{18}O$ stacks and radiocarbon calibration curve, together with estimates of marine reservoir ages that are globally consistent and physically plausible. We follow the same hybrid strategy of relying on both absolute age control points (e.g. radiocarbon ages, tephra horizons) and hypothesis-based age modelling as in version 1.

For this version, benthic foraminifera $\delta^{18}O$ were manually aligned to the relevant regional stacks of Lisiecki and Stern (2016) using mainly the marine isotope stage boundaries as tie points for consistency among the time series and to avoid inflating the chronological confidence. In addition, all radiocarbon ages have been recalibrated to calendar years using IntCal20 (Hogg et al., 2020; Reimer et al., 2020) and model-based estimates of the reservoir age (Butzin et al., 2017). The age-depth models were constructed using the Bayesian algorithm BACON (Blaauw and Christen, 2011) implemented in PDV (Langner and Mulitza, 2019) and are presented as separate elements in the compilation. To avoid extrapolation, we only provide age models for the core depths bracketed by age control points and the age models presented in the original studies may extend further to either side. The age-depth information includes mean, median and the 95% confidence interval of the ages as well as the necessary information to rerun the

https://doi.org/10.5194/essd-2025-599
Preprint. Discussion started: 9 October 2025

age-depth models in BACON and 1,000 posterior age-depth models that can be used for further analysis.

3.3 Seawater temperature estimates

In order to homogenise seawater temperature estimates and to provide a consistent estimate of their uncertainty associated with the calibration and, in case of planktonic Mg/Ca ratios, of the confounding effects of salinity and pH, temperature estimates were recalculated. For seawater temperatures based on the alkenone unsaturation index we used the BAYSPLINE calibration (Tierney and Tingley, 2018) and applied the suggested prior for the standard deviation of sea surface temperature of 5 °C. The resulting estimates represent in general annual mean sea surface temperature. However, for specific regions the temperatures are seasonal averages (Tierney and Tingley, 2018). This seasonality of the estimate is indicated in the metadata. Whenever available, or whenever values could be calculated from inferred seawater temperatures, planktonic foraminifera Mg/Ca ratios were converted to calcification temperature using MgCaRB (Gray and Evans, 2019). In this way we account for the effects of salinity and pH on the Mg/Ca ratios based on sensitivities determined from culture studies. However, as the past salinity and pH variability is unknown for most time series in the synthesis, we, like (Gray and Evans, 2019; Tierney et al., 2019), approximate the temporal evolution of salinity using a scaling to sea level and of pH based on atmospheric pCO_2 from ice cores and the constant disequilibrium from atmospheric CO_2 (DpCO_2) and alkalinity fixed at pre-industrial and modern levels respectively. For each site, we obtained modern sea surface salinity and temperature (needed for the calculation of DpCO_2) from the World Ocean Atlas 2023 (Reagan et al., 2023) from within a circle with a radius of 100 km. Carbonate system parameters (total dissolved inorganic carbon (DIC), its anthropogenic contribution (DIC_anthro) and total alkalinity were derived from the GLODAPv2 gridded data product (Lauvset et al., 2016) in the same way. Since GLODAPv2 does not cover the Gulf of Mexico and the Caribbean Sea, we used the median surface DIC and alkalinity from the GLODAPv2.2023 (Olsen et al., 2016) adjusted cruise data from the area between 10° and 30° N west of 80° W (Barbero et al., 2016a, b, 2019; Jiang et al., 2020; Salisbury, 2017; Salisbury and Shellito, 2019; Wanninkhof et al., 2007, 2014) for the affected time series. For simplicity we assumed global mean DIC_anthro for those sites. Local ocean pCO_2 was subsequently calculated using pre-industrial DIC (DIC-DIC_anthro), alkalinity, salinity and temperature using SeaCarb (Gattuso et al., 2024). Finally, DpCO_2 was calculated as the difference between the calculated oceanic pCO_2 and pre-industrial atmospheric pCO_2 (280

https://doi.org/10.5194/essd-2025-599
Preprint. Discussion started: 9 October 2025

ppm). For the species *Globigerinoides ruber*, *Trilobatus sacculifer*, *Globigerina bulloides* we used the sensitivity of Mg/Ca to temperature, salinity and pH as provided in Gray and Evans (Gray and Evans, 2019). For *Neogloboquadrina pachyderma* and *N. incompta* we used the temperature and salinity sensitivity as used in Boscolo-Galazzo et al. (2025) and ignored the effect of pH as this is poorly constrained for these species. We used the generic calibration for all other species. To account for Mg loss in foraminifera tests that were treated by reductive and oxidative cleaning, we multiplied the respective Mg/Ca ratios by 1.1 to make them comparable with ratios measured on samples that only underwent oxidative cleaning (Barker et al., 2003).
For seawater temperatures derived from both proxies, estimates are presented as the median and 95% confidence intervals. The recalculated values are indicated using the strings “recalc_UKSST” or “recalc_mgcaSST” and accompanied by a note containing the text “Recalculated for PALMOD.”. For further analysis, 1,000 ensemble time series of seawater temperature are provided separately.
Unlike for the two proxy types mentioned above, seawater temperature estimates based on microfossil assemblages were not harmonised. This is because in too many cases the calibration that was used to generate the reported temperature estimates and/or the fossil abundance data on which the estimates are based are not publicly available.

4 Structure, terms and format

The structure of the synthesis has slightly changed since version 1. The main change is the inclusion of the revised age information with the proxy data. These were kept separate in version 1 to highlight the fact that observations on the (core) depth scale are static, whereas the age-depth model can be updated or revised as per user demand. However, this separation into raw and derived data rendered use of the data more complex and we have hence decided to include the revised age data directly with the proxy data. The second change in the structure is the addition of ensembles of seawater temperature time series.

The synthesis is organised by site, which usually is the sediment core from which the data were extracted, but it may also refer to a spliced record comprising multiple sediment cores. Depending on the availability of alkenone or Mg/Ca-derived seawater temperature estimates, each site is associated with information on seven or eight themes. Names in square brackets below are those used in the data files.

https://doi.org/10.5194/essd-2025-599
Preprint. Discussion started: 9 October 2025

- **Geographic data** [site] includes the position of the site in decimal degrees and its water depth in m and, new in this version, the ocean basin in which the site is located. The basin assignment is based on the Global Oceans and Seas dataset, version 1 (Flanders Marine Institute (VLIZ), Belgium, 2021). This theme also contains additional notes that apply to the entire site.
- **Metadata** [meta] contains the original and standardised variable name, units where applicable, information about the origin of the data and where applicable information about the proxy sensor and the seasonal or vertical attribution (as specified by the data generators in the associated manuscript) and the calibration. A complete list of metadata terms is provided in Table 1. Metadata are only included if they were available in the dataset or could be obtained from the accompanying publication. Not all fields are relevant for all parameters (e.g. species is not defined for parameters that are not based on measurements on organisms) and fields that are completely empty for a site are excluded. The metadata now also includes a unique identifier for each time series to facilitate cross-referencing.
- **Chronological data** [chron] includes the information to revise the age-depth model of the site. It contains raw radiocarbon ages, ages based on tephra layers and palaeomagnetics, as provided by the data generators and the ages of the tie points identified for this study. The calendar ages of all tie points are based on the approach outlined above (section Age-depth modelling). Information about the source and the citation of the chronological information is provided. A full list of chronological data terms is provided in Table 2.
- **Proxy data** [data] are presented on a common depth scale. Original ages and original seawater temperature estimates are included, updated seawater temperature estimates are flagged in the notes field using the string “Recalculated for PALMOD”. The standardised parameter names are provided in Table 3.
- **Age-depth model ensembles** [AgeEnsemblesBACON]: 1,000 posterior age-depth models inferred from sediment accumulation rates as modelled using BACON.
- **Seawater temperature ensembles** [SurfaceTempEnsembles]: 1,000 sea water temperature time series for each UK37' or Mg/Ca time series. The ensembles are accompanied by metadata describing the algorithm settings and convergence and details on the species in the case of Mg/Ca.

252 Each site also contains information about the version, import date and date at which the age-depth model was last updated. These fields are largely for internal use.

255 The data are available in serialised R format (*RDS) and structured as a list where the elements contain the information about the themes indicated above. RDS files can be easily read using the open source software R. To ensure interoperability the data product is also available as (simple) JSON formatted data following the LiPD structure and vocabulary.

260 Table 1: metadata fields

261 * Original parameter names are preserved even when they contain errors. These errors have been corrected in the standardised parameter name and additional metadata.

Name	Description
ParameterOriginal	Parameter name as provided in the original data file*
Parameter	Standardised parameter name
ParameterType	Indication of whether the parameter was measured or inferred
ParameterUnit	Unit of the parameter
ParameterAnalyticalError	Parameter uncertainty based on repeat measurements of a standards (not standardised)
ParameterReproducibility	Parameter uncertainty based on repeat measurements of samples (not standardised)
Instrument	Instrument used for the measurements
Laboratory	Laboratory where the measurements were done
SampleThickness_cm	Thickness of the analysed samples in cm
Material	Material on which the measurements were performed or on which the inferred variable is based
Species	Species of foraminifera analysed or on which the inferred parameter is based
SizeFraction_microm	Size range of the foraminifera shells used for the analysis (in µm)

Nshells	Number of foraminifera shells used for analysis
RecordingSeason	Recording season of the proxy as specified by the data generators
RecordingDepth	Recording depth of the proxy as specified by the data generators
CalibrationEquation	Equation used to calculate inferred parameter from measured parameter (usually seawater temperature)
CalibrationUncertainty	Uncertainty of the calibration equation
CalibrationDOI	DOI of the calibration equation
TransferFunctionTrainingSet	Training set used for the development of the transfer function model
TransferFunctionUncertainty	Uncertainty of the transfer function model (RMSE)
TransferFunctionDOI	DOI of the transfer function model
Notes	Notes about the parameter (e.g. the cleaning procedure for Mg/Ca)
PublicationDOI	DOI of the publication describing the data
PublicationLink	Link to the publication describing the data (when no DOI available)
Publication	Publication describing the data (when no DOI or link available)
DataDOI	DOI of the dataset
DataLink	Link where the data were obtained
RetrievalNumber	Retrieval number (for internal use)
TSuID	Unique identifier for the time series

Table 2: chronology data fields

Name	Description

https://doi.org/10.5194/essd-2025-599
Preprint. Discussion started: 9 October 2025

ChronType	Type of chronology tie point (^{14}C, tephra, etc)
ChronDepthMid_cm	Mid depth of the tie point in cm
ChronDepthTop_cm	Top depth of the tie point in cm
ChronDepthBottom_cm	Bottom depth of the tie point in cm
ChronSampleThickness_cm	The thickness of the tie point sample in cm
ChronDatedMaterial	The material dated (usually for ^{14}C)
ChronCalendarAge_kaBP	The median calendar age in ka BP
ChronCalendarAgeMin_kaBP	The 2.5th percentile of the calendar age in ka BP
ChronCalendarAgeMax_kaBP	The 97.5th percentile of the calendar age in ka BP
ChronDatedSpecies	The species (usually foraminifera) dated
ChronNshellsDated	The number of shells (of foraminifera) used for the dating
Chron14CLabcode	The laboratory code for the ^{14}C age
ChronAge14C_kaBP	The ^{14}C age of the sample in ka BP
ChronAge14CError_ka	The uncertainty of the ^{14}C age in ka (1 σ)
ChronAge14CErrorUp_ka	The uncertainty of the ^{14}C age towards younger age in ka (1 σ)
ChronAge14CErrorDown_ka	The uncertainty of the ^{14}C age towards older age in ka (1 σ)
ChronNotes	Notes pertaining to the individual tie point
ChronAgeRejected	An indication of whether the tie point was included in the original age-depth model (boolean)
ChronSource	The source of the chronology information (denoted PALMOD if based on tuned tie point from this study)
ChronDOI	The publication in which the chronology information was presented

https://doi.org/10.5194/essd-2025-599
Preprint. Discussion started: 9 October 2025

5 Description/contents

5.1 Spatial data coverage

Version 2 of the PALMOD marine palaeoclimate data synthesis contains 2,286 time series with one of the eight priority climate-relevant variables each, originating from 475 unique sites (Fig. 1, Table 4). The majority of the newly added time series in this version stem from the tropics. Most time series are of planktonic foraminifera $\delta^{18}O$ (n = 482), with often multiple time series from different species (each with potentially different vertical and seasonal recording preferences) per site. The number of time series with benthic foraminifera $\delta^{18}O$ and with near sea surface temperature closely follow the number of time series with benthic $\delta^{18}O$ (n = 468 and n = 423, respectively). Time series of the other variables are considerably fewer in number. For all variables but biogenic silica content, the highest density of sites is in the Atlantic Ocean. Coverage in the Pacific and the southern hemisphere remains relatively poor, reflecting both historical research focus and the (logistical) challenges of obtaining sediment cores far offshore. In general, sites tend to be located close to the continents, where higher sedimentation rates facilitate the recovery of records with higher temporal resolution.

https://doi.org/10.5194/essd-2025-599
Preprint. Discussion started: 9 October 2025

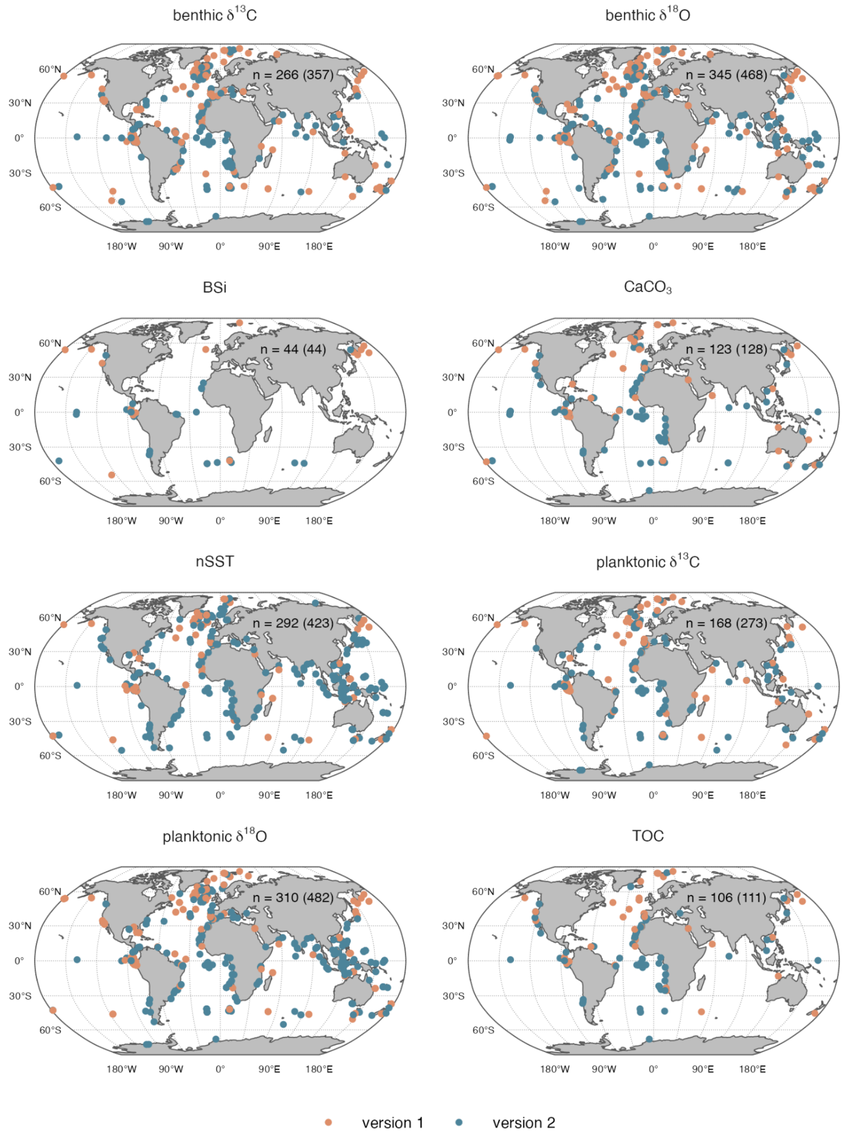

Figure 1: spatial distribution of sites with time series of the eight parameters. Locations are coloured by the version in which they were first included (version 2 also includes all data of version 1). The total number of sites and time series are indicated in brackets.

https://doi.org/10.5194/essd-2025-599
Preprint. Discussion started: 9 October 2025

5.2 Temporal data coverage

Compared to version 1, the temporal coverage has approximately doubled over the 130 kyr time frame and for all variables (Fig. 2). The temporal distribution of data reflects research focus on the last deglaciation, with the highest data density between 10–25 ka BP. Importantly, the coverage does not markedly drop off beyond approximately 40 ka BP, facilitating continuous analysis across the entire last glacial cycle. This coverage pattern is consistent across all variables and has not substantially changed in version 2.

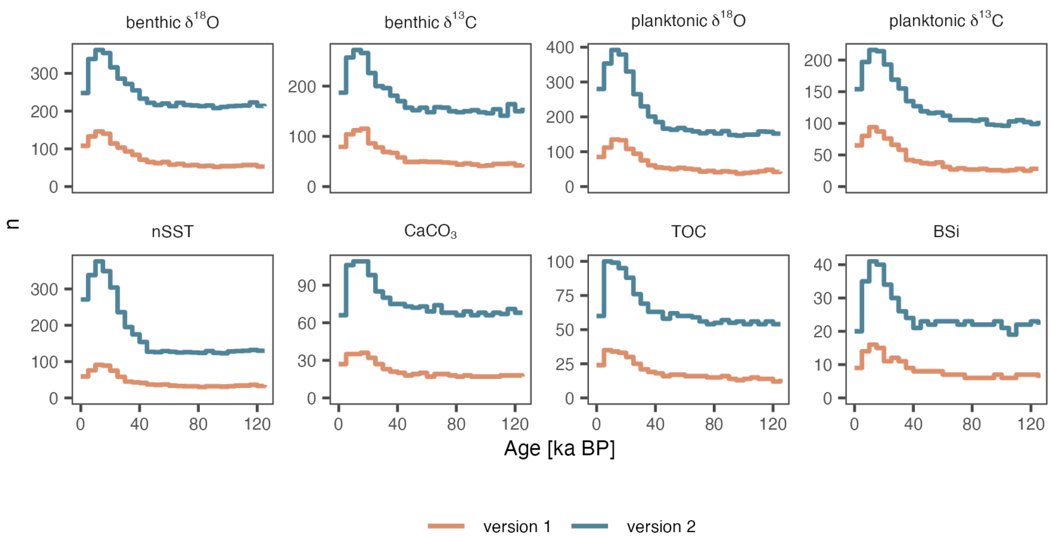

Figure 2: temporal distribution of temporal coverage of each parameter. Lines show the number of time series per 5 kyr bin, colour show the total number of time series for each version. Like in the previous version, version 2 shows highest coverage during the last deglaciation. Note the different scaling on the y axes.

The length of the time series shows a clear bimodal distribution across all variables (Fig. 3). Most time series are shorter than 40 kyr or longer than 110 kyr, reflecting the research focus on investigating either the transition from the last glacial to the Holocene, or glacial-interglacial cycles on long(er) time scales.

https://doi.org/10.5194/essd-2025-599
Preprint. Discussion started: 9 October 2025

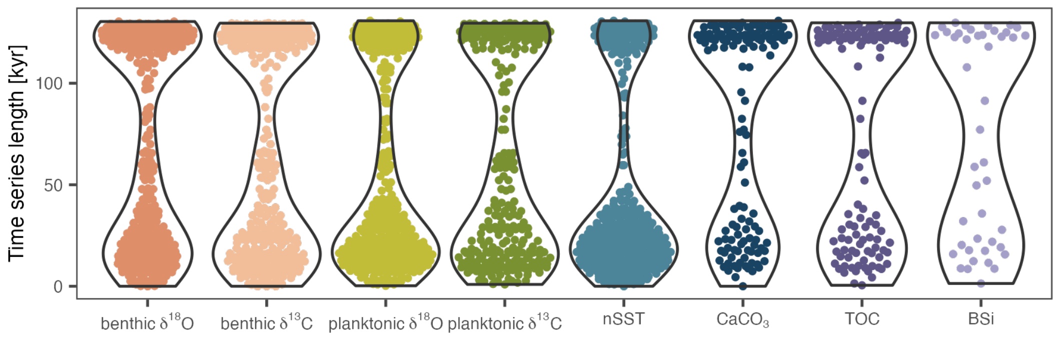

Figure 3: distribution of time series length split by parameter. Time series between 40 and 110 kyr long appear rare across all parameters.

The temporal resolution of the time series varies considerably, but the median temporal resolution of the time series tends to be below 3 kyr (Fig. 4). In general, the highest temporal resolution of the time series is in the youngest part of the 130 kyr time frame (Fig. 4). Even though the resolution decreases with age, this decrease generally stops or reduces around 75 ka BP. The resolution of the time series is, to a first order, related to their length (Fig. 5), reflecting both the challenge of obtaining long sediment cores in high accumulation settings and the amount of work involved in generating the data.

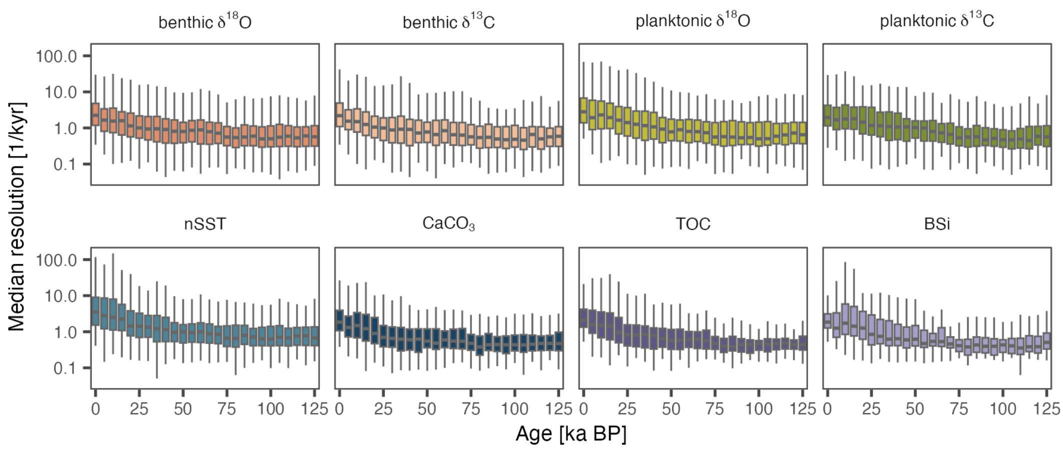

Figure 4: temporal resolution (observations per kyr) of the time series split by parameter. The general trend shows decreasing resolution until approximately 75 ka BP, after which resolution remains more or less constant. Even though there is considerable spread, the median resolution is below 3 kyr across all parameters. Box-whisker plots show distribution of median resolution

https://doi.org/10.5194/essd-2025-599
Preprint. Discussion started: 9 October 2025

per 5 kyr bin; thick lines indicate median values, boxes show interquartile range and whiskers extend to 1.5 times this range.

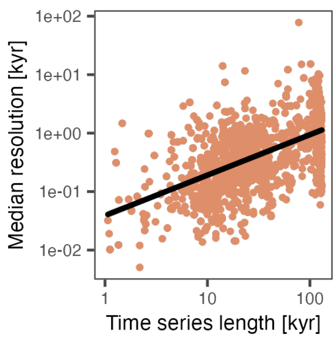

Figure 5: longer time series tend to have lower resolution. Cross plot of median resolution (time between consecutive observations) and time series length. The linear fit (black line) is shown to highlight the general trend; 14 time series shorter than 1 kyr are not shown.

5.3 Chronology

Nearly 90 % of the time series have an age-depth model based on exclusively radiocarbon dating and tuning of benthic foraminifera $\delta^{18}O$ (Fig. 6a). Only five time series have age-depth models entirely based on other - e.g. tephra, biostratigraphy or palaeomagnetics - age controls. The age uncertainty shows to some degree the nature of the dating methods, it tends to be low up to approximately 20 ka BP, reflecting the prevalence of radiocarbon dating within this interval (Fig. 6b). Beyond ca. 20 ka BP, the age uncertainty shows the structure of the benthic foraminifera $\delta^{18}O$ tuning targets with reduced uncertainties near the marine isotope stage boundaries.

https://doi.org/10.5194/essd-2025-599
Preprint. Discussion started: 9 October 2025

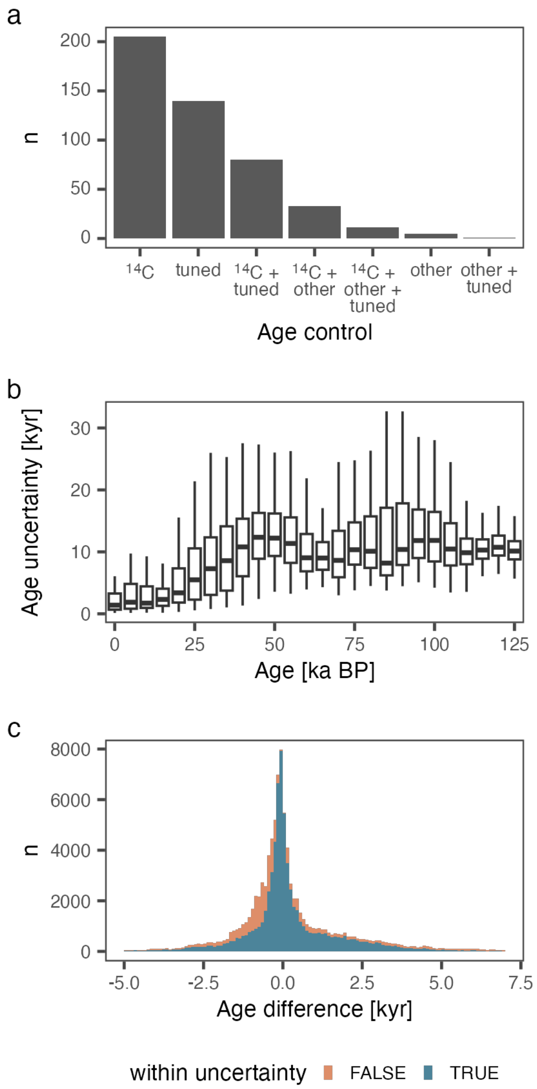

Figure 6: type of age control tie points across all sites (a), age uncertainty across the time series in the dataproduct (b) and differences between the original and updated age-depth models (c). The category "other" in panel a includes tephra, palaeomagnetics and biostratigraphy. Low age uncertainties (b) up to approximately 25 ka BP reflect the prevalence of radiocarbon ages within this interval. The age uncertainty in the older parts of the time series tends to be lower near the boundaries of the marine isotope stages that were used in the construction of the age depth models. Box-whisker plots show the distribution of median age uncertainty (95 % confidence

https://doi.org/10.5194/essd-2025-599
Preprint. Discussion started: 9 October 2025

interval) across the sites per 5 kyr bin. Further explanation of the plots is provided in Figure 4. Colours in c show whether or not the difference between the age estimates is within the 95 % CI of the revised age-depth model. In 2 % of the data points the difference is outside the range shown here.

The revised age-depth models differ in many cases from the original age-depth models (Fig 6c). However, these differences are small, the median difference (revised - original) is -0.07 kyr (-3.28 – 5.24, 95 % CI) and for 74 % of all data points the difference is within the uncertainty of the revised age-depth model. These differences are to some degree due to the different approaches used to model the age-depth relationship and/or to differences in the radiocarbon calibration curve, the applied reservoir age, the tuning parameters and the tuning targets.

5.4 Near sea surface temperature

The majority of the near sea surface temperature time series (n = 173) is based on planktonic foraminifera Mg/Ca (Fig. 7a). Near sea surface temperature estimates based on alkenone unsaturation indices and microfossil assemblages (predominantly planktonic foraminifera) make up approximately equal proportions (n = 119 and 115, respectively). Only 16 time series are based on other proxies, including TEX86 and LDI. Twenty-nine sites have near sea surface temperature estimates based on the Mg/Ca of more than one species of planktonic foraminifera and 55 sites have near sea surface temperature time series based on more than one proxy (Fig. 7a), thus potentially allowing for comparison and/or the reconstruction of seasonal or vertical temperature gradients. The uncertainty of the revised near sea surface temperature estimates (1 SD) remains approximately constant through time and its median value across all samples is

https://doi.org/10.5194/essd-2025-599
Preprint. Discussion started: 9 October 2025

Open Access Earth System Science Data Discussions

0.93 °C (0.64–2.44 °C, 95%).

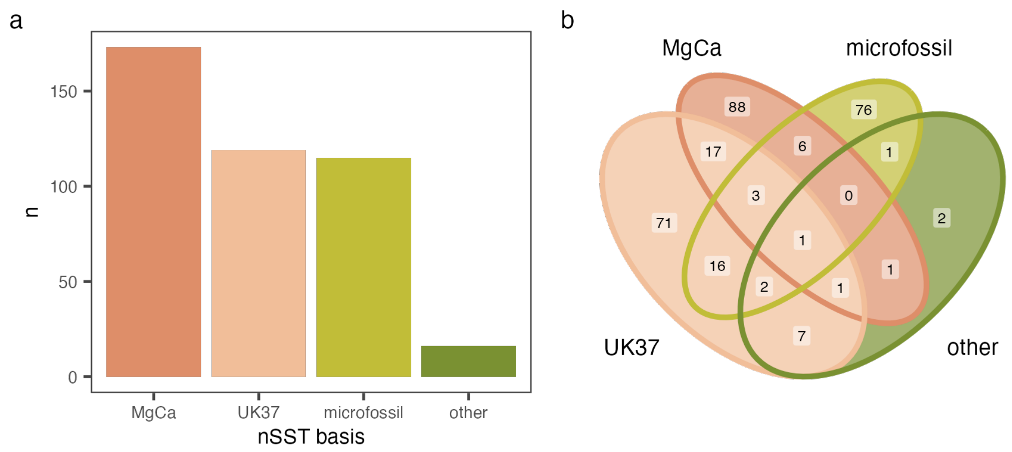

Figure 7: Number of the near sea surface temperature time series sorted by proxy (a) and a Venn diagram showing the overlap among records based on different proxies across the sites (b; numbers indicated). In total 55 sites have near sea surface temperature data based on more than one proxy.

6 Data availability

Data is freely available at https://doi.pangaea.de/10.1594/PANGAEA.984602 (Jonkers et al., 2025b). The data can also be visualised and downloaded in LiPD format from https://lipdverse.org/PalMod/current_version/ (last access: September 30, 2025). We explicitly encourage users to also cite the original data when using this data product.

7 Usage notes

General comments on data usage and potential applications can be found in Jonkers et al. (2020). The PALMOD synthesis contains data about sediment composition (calcium carbonate, organic carbon and biogenic silica content) that is relatively straightforward to interpret. The

https://doi.org/10.5194/essd-2025-599
Preprint. Discussion started: 9 October 2025

data product also contains information derived from measurements on biological material (foraminifera stable carbon and oxygen isotope ratios) and estimates of seawater derived indirectly from the chemical or species composition of microfossils or from biomarkers. The biological origin of the data renders its interpretation less straightforward as environmental preferences of the organisms may affect the recorded climate signal. A detailed description of the proxy sensors and the intricacies of the proxies is provided in the data descriptor of version 1 (Jonkers et al., 2020). We encourage users to read the relevant section. A general proxy system modelling framework for marine sediment time series can e.g. be found in Dolman and Laepple (2018). In this section we focus on the main advance compared to version 1 that is relevant to usage: the harmonisation of seawater temperature estimates.

Estimates of near sea surface temperature based on planktonic foraminifera Mg/Ca and UK37' have been updated and harmonised whenever possible. For UK37', these updated estimates required relatively little user input, but the use of different priors may affect the results. Since planktonic foraminifera Mg/Ca is not only affected by seawater temperature, the inference of Mg/Ca-based temperatures is more complex. Estimates of salinity and pH are indirect and, by necessity, rather crude as they ignore existing, but unknown, spatiotemporal variation. Importantly, the estimates of salinity and pH depend on the age and updates to the age-depth model therefore require recalculation of the inferred temperatures. The influence of these nuisance factors can in principle also be corrected using measured estimates of ocean pH based on boron isotope ratios (Gray and Evans, 2019) or indirectly by using oxygen isotopes (Morley et al., 2024), but this requires additional data that is not available for all time series. We have hence chosen a correction approach that is consistent across all time series. Whilst for the species *Globigerinoides ruber*, *Trilobatus sacculifer*, *Globigerina bulloides*, *Neogloboquadrina pachyderma* and *N. incompta* the sensitivity of Mg/Ca to temperature, salinity and pH is well constrained, this is not the case for other, generally deeper dwelling species. For these other species we have used the generic calibration. Care thus needs to be taken with the temperature estimates based on this calibration and we encourage the use of anomalies, rather than reliance on absolute values. To allow users to compare the harmonised seawater temperature estimates with the values provided by the data generators as a sanity check. Users may also want to use different calibration (schemes). For this purpose, the synthesis also contains the raw UK37' and Mg/Ca values.

Seawater temperatures based on microfossil assemblage composition are included in the synthesis only in the form as reported by the authors. Because of the fragmentary nature of the required metadata, the originally reported estimates could not be updated to a common standard and are associated with uncertainty estimates only where the data generators provided them. From the accompanying publications it is not always clear how the uncertainty has been derived and the methods certainly vary among the different studies because of personal preferences and methodological progress on how to deal with issues like spatial autocorrelation. In light of new insights regarding the uncertainty of seawater temperature estimates based on microfossil assemblages (Telford et al., 2013; Trachsel and Telford, 2016), the reported uncertainties are likely too optimistic. Interested users can refer to Jonkers et al. (2023) for an example of comprehensive estimates of calibration uncertainty associated with planktonic foraminifera assemblage derived seawater temperatures.

Whenever publicly available, the original age-depth models are included in the data product, but they almost universally lack uncertainty estimates. Still, these original age estimates can be used for a comparison of the revised and original age models. Future updates to the radiocarbon calibration curve, to the reservoir age estimates, or the stacks may require updating the age-depth models. The raw chronology data provided in the data product enables this updating in an automated fashion. Please note that the Mg/Ca-based temperature estimates depend on the age of the samples for a correction of the effects of salinity and pH. The temperature estimates thus need to be updated if the age-depth model is revised. Uncertainty estimates on the chronology are to some degree method dependent, but the Bayesian approach we utilised appears to provide reasonable results (Trachsel and Telford, 2017). However, our approach ignores additional uncertainty caused by bioturbation and uncertainty related to alignment of the benthic foraminifera $\delta^{18}O$ records. Recent work suggests ways to incorporate these sources of uncertainty (Lee et al., 2023). Other approaches may thus provide different results and the user may wish to compare age-depth models using different age-depth modelling strategies like for instance done in the Speleothem Isotope Synthesis and Analyses database version 2 (Comas-Bru et al., 2020).

Some example scripts for filtering the data product by location, length, resolution and age control are available from the lead author's GitHub repository (https://github.com/lukasjonkers/PALMODutils, last access September 17, 2025). An extensive documentation of the LiPD format is available at https://lipdverse.org (last access: 23 May 2025)

https://doi.org/10.5194/essd-2025-599
Preprint. Discussion started: 9 October 2025

and utilities to interact with LiPD files in R, Matlab and Python are available at https://github.com/nickmckay/LiPD-utilities (last access: 23 May 2025).

Whilst we have done our best to address errors and omissions and aimed for standardisation across the entire data product, it comes with the guarantee of remaining errors and inconsistencies. Users are encouraged to report those to the lead author so they can be corrected.

8 Recommendations for palaeoclimate data stewardship

This synthesis would not have been possible without good data stewardship of the marine palaeoclimate science community. For many decades researchers have been sharing their research data through (dedicated) publicly accessible data repositories. Even so, this synthesis makes a lot of invaluable metadata and chronological information publicly available for the first time. This is because such metadata and chronology data is often not directly associated with the primary proxy data, but reported in accompanying publications instead. When these publications are publicly accessible, this important information to interpret and reuse the data can be retrieved with considerable additional effort. However, more often than not, the publications are not publicly available and the information remains hidden behind the paywalls of publishers, rendering the data difficult to reuse.

Community guidelines on how to report general palaeoclimate data are available (Khider et al., 2019), as are more specific guidelines for microfossil assemblage data (Jonkers et al., 2025a). However, legacy datasets invariantly do not adhere to such guidelines, thus necessitating (community) effort to increase the reusability of these data. For new datasets, we recommend data sharing not only from the point of view of reproducing single studies, but explicitly consider reuse when sharing data and ensure that that research data files are scientific works that are comprehensible in themselves. In this way, reuse and reinterpretation of scientific data and knowledge is greatly facilitated, allowing our field to address new questions that cannot be answered using a single palaeoclimate time series.

https://doi.org/10.5194/essd-2025-599
Preprint. Discussion started: 9 October 2025

The lack of a standardised vocabulary and consistent ontology also remains a consistent hurdle to reusability. Progress is made in this regard at the two largest repositories for palaeo(climate) data, at NCDC visibly (Morrill et al., 2021) and more under the hood at PANGAEA (Felden et al., 2023). Structured and standardised data can be accessed at PANGAEA in xml format. Future synthesis efforts can benefit from this standardisation, but it requires that data generators share their data through these recognised and specific community repositories.

The value of this data product arguably not only lies in the standardisation of the format and vocabulary, but also in the updating and standardisation of the age-depth models and of the seawater temperature estimates. Such updating and standardisation is only possible when raw chronology and proxy data are available on a depth scale. Radiocarbon data is often publicly available or can, with additional effort, be scraped from publications. However, information on aligned chronologies, including ages and uncertainty on tuning tie points is seldom reported, rendering reevaluation of such chronologies difficult. Regarding proxy data, measured Mg/Ca and UK37' can, provided the calibration equation is known, be calculated from reported seawater temperatures, but ambiguities are likely to remain and the chance of deriving erroneous values is non-negligible (especially when the calibration equation is not explicitly included in the data file, or provided in secondary publication). For seawater temperatures based on microfossil assemblage the situation is different. Raw assemblage data are not as often shared as geochemical proxy data and due to the multi-dimensional character of the data, raw assemblage data cannot be inferred from the temperature estimates. This not only prevents revising temperature estimates reported without the underlying raw count data, but also prevents reuse of such assemblage data in other contexts, such as for estimates of past biodiversity change (e.g. Strack et al., 2024). This is unfortunate given the tremendous effort that went into generating such species assemblage data. In our opinion, the amount of work and the relevance of such data is so large that it would justify a coordinated international action to rescue the unpublished microfossil counts underlying seawater temperature reconstructions.

Acknowledgements

We are grateful to all researchers who generously shared their data and responded to requests for information. We thank Nick McKay for help with converting the data product to LiPD format and Anjuly Janßen for help with sorting out the bibliography.

https://doi.org/10.5194/essd-2025-599
Preprint. Discussion started: 9 October 2025

Funding

This project was supported by the German Federal Ministry of Research, Technology and Space (BMFTR) as a Research for Sustainability initiative (FONA) through the PALMOD project (grant nos. 01LP1922A and 01LP2308A). MH acknowledges funding by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation), Cluster of Excellence “The Ocean Floor— Earth's Uncharted Interface” (EXC 2077, grant no. 390741603).

https://doi.org/10.5194/essd-2025-599
Preprint. Discussion started: 9 October 2025

Table 3: standardised parameter names.

Parameter	Description
benthic.d18O	benthic foraminifera stable oxygen isotope ratio
benthic.d13C	benthic foraminifera stable carbon isotope ratio
planktonic.d18O	planktonic foraminifera stable oxygen isotope ratio
planktonic.d13C	planktonic foraminifera stable carbon isotope ratio
surface.temp	(near) sea surface temperature
deep.temp	bottom water temperature
CaCO3	$CaCO_3$ content
TOC	Total organic carbon content
BSi	Biogenic silica content
DBD	Dry bulk density
IRD	Ice-rafted detritus
planktonic.MgCa	planktonic foraminifera Mg/Ca ratio
benthic.MgCa	benthic foraminifera Mg/Ca ratio
UK37	alkenone unsaturation index (rare cases where this ratio is not expressed as UK37` are indicated in the Notes)
C37.concentration	alkenone concentration

https://doi.org/10.5194/essd-2025-599
Preprint. Discussion started: 9 October 2025

Table 4: sites included in the PALMOD 130k marine palaeoclimate data synthesis version 2.

site	doi	reference
108_658	10.2312/reports-gpi.1991.46 & 10.2973/odp.proc.sr.108.169.1989	Tiedemann (1991) Tiedemann et al. (1989)
108_658C	10.1594/PANGAEA.227736 & 10.1016/S0277-3791(99)00081-5 & 10.1029/94PA03354 & 10.1126/science.288.5474.2198	Knaack and Sarnthein (2005) deMenocal et al. (2000a) Zhao et al. (1995) deMenocal et al. (2000b)
108_659	10.2312/reports-gpi.1991.46	Tiedemann (1991)
108_664B	10.1029/97PA01019 & 10.2973/odp.proc.sr.108.165.1989	Raymo et al. (1997) Ruddiman and Janecek (1989)
117_723A	10.1029/95GL02558 & 10.1038/nature01340 & 10.1016/j.marmicro.2010.09.006 & 10.1016/S0031-0182(03)00629-1	Naidu and Malmgren (1995) Gupta et al. (2003) Godad et al. (2011) Naidu and Niitsuma (2003)
121_758	10.1029/94PA02290 & 10.2973/odp.proc.sr.121.124.1991	Chen et al. (1995) Farrell and Janecek (1991)
130_806B	10.2973/odp.proc.sr.130.023.1993 & 10.1007/BF02369003 & 10.2973/odp.proc.sr.130.025.1993 & 10.2973/odp.proc.sr.130.024.1993 & 10.1126/science.1115933 & 10.2973/odp.proc.ir.130.1991 & 10.2973/odp.proc.sr.130.002.1993	Berger et al. (1993) (Berger et al., 1993) (1996) Bickert et al. (1993) Schmidt et al. (1993) Medina-Elizalde and Lea (2005) Kroenke et al. (1991) Janecek (1993)
133_819A	10.2973/odp.proc.sr.133.224.1993	Wanninkhof et al. (2014)
154_925C	10.2973/odp.proc.sr.154.110.1997 & 10.5194/cp-13-779-2017	Bickert et al. (1997) Wilkens et al. (2017)
154_927	10.2973/odp.proc.sr.154.110.1997 & 10.5194/cp-13-779-2017	Bickert et al. (1997) Wilkens et al. (2017)
154_929	10.2973/odp.proc.sr.154.110.1997 & 10.5194/cp-13-779-2017	Bickert et al. (1997) Wilkens et al. (2017)
160_963A	10.1016/j.palaeo.2011.04.030	Incarbona et al. (2011)
161_976	10.1130/0091- 7613(2002)030<0863:EAAAHP>2.0.CO; 2 & 10.1016/j.quascirev.2014.06.016 & 10.1002/2014PA002710	Combourieu Nebout et al. (2002) Martrat et al. (2014) Jiménez-Amat and Zahn (2015)
162_983	10.1029/1998PA900021 & 10.1038/nature14330 & 10.1016/S0012- 821X(97)00164-7 & 10.1029/2003PA000921	Ortiz et al. (1999) Barker et al. (2015) Channell et al. (1997) Raymo et al. (2004)
167_1011C	10.2973/odp.proc.sr.167.225.2000 &	Andreasen et al. (2000)

https://doi.org/10.5194/essd-2025-599
Preprint. Discussion started: 9 October 2025

	10.2973/odp.proc.sr.167.214.2000	Lyle et al. (2000)
167_1014	10.2973/odp.proc.sr.167.205.2000 & 10.1029/2004GL020138	Hendy and Kennett (2000) Yamamoto et al. (2004)
167_1017E	10.2973/odp.proc.sr.167.242.2000 & 10.2973/odp.proc.sr.167.210.2000 & 10.2973/odp.proc.sr.167.222.2000	Kennett et al. (2000) Ishiwatari et al. (2000) Tada et al. (2000)
167_1018C	10.2973/odp.proc.sr.167.225.2000 & 10.2973/odp.proc.sr.167.214.2000	Andreasen et al. (2000) Lyle et al. (2000)
167_1019C	10.1029/GM112p0127 & 10.1029/2002PA000768	Mix et al. (1999) Barron et al. (2003)
172_1058C	10.1016/j.gloplacha.2013.08.013	Bahr et al. (2013)
172_1059A	10.1029/2000PA000527	Oppo et al. (2001)
175_1078C	10.5194/cp-4-107-2008 & 10.1029/2003GL017557 & 10.1029/2011PA002118	Dupont et al. (2008) Kim et al. (2003) Hessler et al. (2011)
175_1087A	10.2973/odp.proc.sr.175.230.2001	Pierre et al. (2001)
177_1089	10.2973/odp.proc.sr.177.120.2003 & 10.1029/2007PA001457 & 10.2973/odp.proc.ir.177.1999	Hodell et al. (2003a) Cortese et al. (2007) Gersonde et al. (1999)
181_1123	10.1126/science.1221294 & 10.1016/j.gloplacha.2008.07.003 & 10.2973/odp.proc.sr.181.209.2002 & 10.2973/odp.proc.sr.181.205.2002	Elderfield et al. (2012) Hayward et al. (2008) Weedon and Hall (2002) Suzuki et al. (2002)
182_1132B	10.1029/2001PA000643 & 10.2973/odp.proc.sr.182.003.2002	Holbourn et al. (2002) Brooks et al. (2002)
184_1143	10.1016/j.epsl.2006.09.028 & 10.1016/j.epsl.2011.04.016	Tian et al. (2006) Li et al. (2011)
184_1144A	10.2973/odp.proc.ir.184.2000 & 10.1016/j.palaeo.2007.03.005	Wang et al. (2000) Wei et al. (2007)
184_1146	10.2973/odp.proc.sr.184.214.2003 & 10.1126/science.1185435	Clemens and Prell (2003) Herbert et al. (2010)
184_1147	10.1029/2007PA001552 & 10.2973/odp.proc.sr.184.223.2004 & 10.1016/j.palaeo.2013.02.031 & 10.1016/j.quascirev.2017.08.005	Tian et al. (2008) Cheng et al. (2004) Li et al. (2013) Li et al. (2017)
186_1150A	10.1016/j.marmicro.2010.01.003	Koizumi and Yamamoto (2010)
202_1233	10.1126/science.1097863 & 10.1016/j.epsl.2007.04.040 & 10.1016/j.quascirev.2010.03.005 & 10.1029/2005PA001146	Lamy et al. (2004) Lamy et al. (2007) Kaiser and Lamy (2010) Kaiser et al. (2005)

202_1240	10.1002/jqs.2582 & 10.1002/2017PA003133 & 10.1016/j.quascirev.2019.106065 & 10.1029/2008PA001620	Yu et al. (2012) Jacobel et al. (2020) Pena et al. (2008)
202_1242	10.1029/2005PA001208 & 10.1038/s41586-018-0589-x	Benway et al. (2006) Hoogakker et al. (2018)
303_U1308	10.1029/2008PA001591	Hodell et al. (2008)
323_U1340A	10.1029/2012PA002365	Schlung et al. (2013)
3cBx	10.1016/j.palaeo.2012.06.002	Sagawa et al. (2012)
81_552A	10.2973/dsdp.proc.81.116.1984	Shackleton and Hall (1984)
90_594	10.1016/S0377-8398(97)00025-X & 10.1029/93PA01162	Wells and Okada (1997) Nelson et al. (1993)
A7	10.1029/2004PA001061	Sun et al. (2005)
AAS_9_21	10.1029/2008PA001687	Govil and Naidu (2010)
AC85_4	10.1029/91PA00501	Grazzini and Pierre (1991)
AHF_16832	10.1029/96PA01236 & 10.1029/1999PA000375	Mortyn et al. (1996) Stott et al. (2000)
AII107_131	10.1029/GM029p0360	Boyle (1984)
ASV13_1200	10.1016/s0921-8181(02)00116-9 & 10.1029/2004PA001116	Ivanova (2002) Duplessy et al. (2005)
B997_328	10.1002/jqs.841	Castañeda et al. (2004)
B997_330	10.1002/jqs.841	Castañeda et al. (2004)
BJ8_03_13GGC	10.1038/NGEO920	Linsley et al. (2010)
BJ8_03_70GGC	10.1038/NGEO920	Linsley et al. (2010)
BOFS31_1K	10.1029/96PA00041 & 10.1029/94PA03353 & 10.1029/94PA03354 & 10.1038/35013033	Wanninkhof et al. (2014) Beveridge et al. (1995) Zhao et al. (1995) Elderfield and Ganssen (2000)
BOFS5K	10.1029/94PA03062 & 10.1594/PANGAEA.859221 & 10.2312/reports-ifg.2001.13 & 10.1029/94PA03040	Manighetti et al. (1995) Lowry and Machin (2016) Vogelsang et al. (2001) Maslin et al. (1995)
BP00_07_05	10.1594/PANGAEA.124310 & 10.1594/PANGAEA.124311 & 10.1016/j.margeo.2004.01.008 & 10.1111/j.1502-3885.2005.tb01099.x	Simstich (2010a) Simstich (2010b) Simstich et al. (2004) Simstich et al. (2005)
BS79_33	10.1016/S0016-7037(98)00097-0 & 10.1029/2000PA000502	Müller et al. (1998) Cacho et al. (2001)

CD17_30	10.1029/94PA02514	Otto et al. (1995)
CH07_98_GGC_19	10.1029/2004PA001074 & 10.1029/2006GL028495	Keigwin et al. (2005) Sachs (2007)
CH69_K09	10.5194/cp-8-483-2012 & 10.1029/1998PA900004	Govin et al. (2012) Cortijo et al. (1999)
CH73_139	10.1594/PANGAEA.726215 & 10.1016/0031-0182(85)90069-0	Duplessy (1982b) Labeyrie and Duplessy (1985)
CHAT1K	10.1029/97PA02982	Weaver et al. (1998)
CHAT_16k	10.1016/j.quascirev.2008.07.010 & 10.1029/2006PA001347	McCave et al. (2008) Yu et al. (2007)
CHN82_24_4PC	10.1016/0011-7471(72)90033-2 & 10.1016/0012-821x(85)90154-2	Ku et al. (1972) Boyle and Keigwin (1985)
CV15025_GC_07_01	10.1016/j.quascirev.2019.106004	Curran et al. (2019)
D13882	10.1594/PANGAEA.718856 & 10.1029/2008GC002367 & 10.1016/j.quascirev.2010.04.004	Alt-Epping (2008) Rodrigues et al. (2009) Rodrigues et al. (2010)
D13902	10.1016/j.quascirev.2004.04.009 & 10.1029/2008GC002367 & 10.1016/j.marmicro.2015.03.001	Abrantes et al. (2005) Rodrigues et al. (2009) Bartels-Jónsdóttir et al. (2015)
ELT49_019_PC	10.1029/91PA02477	Charles et al. (1991)
EW9209_1JPC	10.1029/96PA02413	Curry and Oppo (1997)
EW9209_2JPC	10.1029/GM112p0059	Curry et al. (1999)
EW9209_3JPC	10.1029/GM112p0059 & 10.1007/978-3-642-80353-6_29	Curry et al. (1999) Curry (1996)
EW9302_JPC8	10.1029/96pa03133 & 10.1029/1998PA900004	Oppo et al. (1997) Cortijo et al. (1999)
EW9504_02PC	10.1029/1999PA000375	Stott et al. (2000)
EW9504_03PC	10.1029/1999PA000375	Stott et al. (2000)
EW9504_04PC	10.1029/1999PA000375	Stott et al. (2000)
EW9504_05PC	10.1029/1999PA000375	Stott et al. (2000)
EW9504_08PC	10.1029/1999PA000375	Stott et al. (2000)
EW9504_09PC	10.1029/1999PA000375	Stott et al. (2000)
EW9504_17PC	10.2973/odp.proc.sr.167.214.2000	(Lyle et al., 2000)
FR01_97_12	10.1029/2004PA001047 & 10.1016/j.margeo.2008.11.003	Bostock et al. (2004) Bostock et al. (2009)
FR1_94_GC3	10.1080/08120099.2018.1495101	De Deckker et al. (2019)

GIK11944_2	10.2312/reports-sfb313.1993.41	Weinelt (1993)
GIK12310_4	10.2312/reports-gpi.1991.45 & 10.2312/reports-ifg.2001.13	Winn et al. (1991) Vogelsang et al. (2001)
GIK12329_6	10.1029/93PA03301 & 10.2312/reports-ifg.2001.13	Sarnthein et al. (1994) Vogelsang et al. (2001)
GIK12379_3	10.1029/93PA03301	Sarnthein et al. (1994)
GIK12392_1	10.1029/93PA03301 & 10.2312/reports-ifg.2001.13 & 10.1007/978-3-642-68409-8_25	Sarnthein et al. (1994) Vogelsang et al. (2001) Thiede et al. (1982)
GIK13289_2	10.1029/93PA03301	Sarnthein et al. (1994)
GIK13519_1	10.2312/reports-gpi.1991.45 & 10.1029/PA001i001p00027	Winn et al. (1991) Zahn et al. (1986)
GIK15612_2	10.1029/93PA03301 & 10.2312/reports-gpi.1998.90	Sarnthein et al. (1994) Kiefer (1998)
GIK15627_3	10.1029/93PA03301 & 10.2312/reports-ifg.2001.13	Sarnthein et al. (1994) Vogelsang et al. (2001)
GIK15637_1	10.1594/PANGAEA.106213 & 10.1029/93PA03301 & 10.2312/reports-gpi.1998.90	Zahn-Knoll (1986) Sarnthein et al. (1994) Kiefer (1998)
GIK15666_6	10.1029/93PA03301	Sarnthein et al. (1994)
GIK15669_1	10.1029/93PA03301 & 10.2312/reports-ifg.2001.13	Sarnthein et al. (1994) Vogelsang et al. (2001)
GIK15672_1	10.1029/93PA03301	Sarnthein et al. (1994)
GIK16030_1	10.1029/93PA03301	Sarnthein et al. (1994)
GIK16396_1	10.1029/2002PA000772	Weinelt et al. (2003b)
GIK16397_2	10.2312/reports-ifg.2001.13 & 10.1029/95PA01453	Vogelsang et al. (2001) Sarnthein et al. (1995)
GIK16402_2	10.1594/PANGAEA.544626 & 10.1029/93PA03301	Mienert (1985) Sarnthein et al. (1994)
GIK16520_1	10.1594/PANGAEA.807876	Winn et al. (2013)
GIK16527_1	10.1594/PANGAEA.807876	Winn et al. (2013)
GIK16772_2	10.1029/93PA03301 & 10.2312/reports-ifg.2001.13	Sarnthein et al. (1994) Vogelsang et al. (2001)
GIK16867_2	10.1029/93PA03301 & 10.2312/reports-ifg.2001.13	Sarnthein et al. (1994) Vogelsang et al. (2001)
GIK17045_2	10.1594/PANGAEA.54393	Sarnthein (1997)
GIK17045_3	10.1029/93PA03301	Sarnthein et al. (1994)
GIK17049_6	10.2312/reports-sfb313.1996.61 &	Jung (1996)

https://doi.org/10.5194/essd-2025-599
Preprint. Discussion started: 9 October 2025

	10.2312/reports-ifg.2001.13	Vogelsang et al. (2001)
GIK17051_3	10.2312/reports-sfb313.1996.61 & 10.2312/reports-ifg.2001.13	Jung (1996) Vogelsang et al. (2001)
GIK17286_1	10.1029/2019PA003646	Lauterbach et al. (2020)
GIK17730_4	10.2312/reports-sfb313.1993.41 & 10.2312/reports-ifg.2001.13	Weinelt (1993) Vogelsang et al. (2001)
GIK17748_2	10.1016/j.epsl.2008.04.043 & 10.1016/S0277-3791(02)00012-4	Mohtadi et al. (2008) Kim et al. (2002b)
GIK17927_2	10.1007/s00531-015-1227-6	Sadatzki et al. (2016)
GIK17940_2	10.1016/S0025-3227(98)00182-0 & 10.1029/1998PA900015 & 10.1029/1999PA900028 & 10.1016/S0025-3227(98)00177-7 & 10.1016/j.chemgeo.2012.07.024	Wang et al. (1999a) Pelejero et al. (1999) Wang et al. (1999b) Jian et al. (1999) Hu et al. (2012)
GIK17961_2	10.1016/S0025-3227(98)00182-0 & 10.1029/1998PA900015	Wang et al. (1999a) Pelejero et al. (1999)
GIK18252_3	10.1126/science.1057131	Kienast et al. (2001)
GIK18287_3	10.1006/qres.2001.2235	Steinke et al. (2001)
GIK18462_3	10.1029/2010PA001934	Xu et al. (2010)
GIK18471_1	10.1016/j.palaeo.2016.09.010	Lo Giudice Cappelli et al. (2016)
GIK18519_2	10.1029/2018PA003323	Schröder et al. (2018)
GIK18522_3	10.1029/2018PA003323	Schröder et al. (2018)
GIK18526_3	10.1029/2018PA003323	Schröder et al. (2018)
GIK18540_3	10.1029/2018PA003323	Schröder et al. (2018)
GIK23065_2	10.2312/reports-sfb313.1990.23 & 10.2312/reports-ifg.2001.13	Vogelgesang (1990) Vogelsang et al. (2001)
GIK23074_1	10.2312/reports-ifg.2001.13 & 10.2312/reports-ifg.1999.9	Vogelsang et al. (2001) Voelker (1999)
GIK23258_2	10.1111/j.1502-3885.2003.tb01227.x & 10.1016/S0146-6380(03)00084-6	Sarnthein et al. (2003) Martrat et al. (2003)
GIK23258_3	10.1111/j.1502-3885.2003.tb01227.x	Sarnthein et al. (2003)
GIK23414_9	10.2312/reports-sfb313.1996.61 & 10.2312/BzPM_0456_2003	Jung (1996) Kandiano (2003)
GIK23415_9	10.2312/reports-sfb313.1996.61 & 10.1127/zdgg/154/2003/47	Jung (1996) Weinelt et al. (2003a)
GIK23416_4	10.2312/reports-sfb313.1996.61	Jung (1996)
GIK23417_1	10.2312/reports-sfb313.1996.61	Jung (1996)

GIK23418_8	10.2312/reports-sfb313.1996.61	Jung (1996)
GIK23419_8	10.2312/reports-sfb313.1996.61	Jung (1996)
GIK23519_5	10.1111/j.1502-3885.2006.tb01112.x	Millo et al. (2008)
GL1090	10.1016/j.epsl.2017.01.014 & 10.1016/j.gloplacha.2017.09.006 & 10.1002/2017GL074457 & 10.1029/2019PA003653 & 10.1016/j.quascirev.2020.106307	Santos et al. (2017a) Lessa et al. (2017) Santos et al. (2017b) Ballalai et al. (2019) Santos et al. (2020)
GS07_150_17_1 GC_A	10.1002/2017PA003095 & 10.1016/j.epsl.2015.05.032	Voigt et al. (2017) Freeman et al. (2015)
GeoB10029_4	10.1016/j.epsl.2010.01.024	Mohtadi et al. (2010a)
GeoB10038_4	10.1016/j.epsl.2010.01.024 & 10.1016/j.quascirev.2009.12.006	Mohtadi et al. (2010a) Mohtadi et al. (2010b)
GeoB10042_1	10.2458/azu_js_rc.55.16384 & 10.1002/2015PA002802	Southon (2013) Setiawan et al. (2015)
GeoB10043_3	10.2458/azu_js_rc.55.16384 & 10.1002/2015PA002802	Southon (2013) Setiawan et al. (2015)
GeoB10065_7	10.1016/j.quascirev.2014.04.006 & 10.1002/2014GL061450	Steinke et al. (2014a) Steinke et al. (2014b)
GeoB10069_3	10.1016/j.epsl.2013.11.032	Gibbons et al. (2014)
GeoB1016_3	10.1002/2013GL058999 & 10.1007/978-3-642-80353-6_27 & 10.1007/978-3-642-78737-9_15 & 10.1029/94PA03308 & 10.1029/96PA03640	Govin et al. (2014a) Schneider et al. (1996) Müller et al. (1994) Schneider et al. (1995) Schneider et al. (1997)
GeoB1023_5	10.1016/S0012-821X(01)00545-3 & 10.1144/GSL.SP.1992.064.01.19	Kim et al. (2002a) Schneider et al. (1992)
GeoB1032_3	10.1007/978-3-642-80353-6_30 & 10.1007/978-3-642-18917-3_26 & 10.1007/978-3-642-80353-6_25	Bickert and Wefer (1996) Volbers et al. (2003) Wefer et al. (1996)
GeoB1034_3	10.1007/978-3-642-80353-6_30	Bickert and Wefer (1996)
GeoB1035_4	10.1007/978-3-642-80353-6_30	Bickert and Wefer (1996)
GeoB1041_3	10.1007/978-3-642-80353-6_30	Bickert and Wefer (1996)
GeoB1101_5	10.1007/978-3-642-80353-6_30	Bickert and Wefer (1996)
GeoB1105_3	10.1007/978-3-642-80353-6_30 & 10.1007/978-3-642-58646-0_1 & 10.1029/1999PA000370 & 10.1007/978-3-642-80353-6_25 & 10.1007/978-3-642-80353-6_27	Bickert and Wefer (1996) Wefer et al. (1999) Nürnberg et al. (2000) Wefer et al. (1996) Schneider et al. (1996)

https://doi.org/10.5194/essd-2025-599
Preprint. Discussion started: 9 October 2025

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GeoB1113_4	10.1029/93PA03301	Sarnthein et al. (1994)
GeoB1115_3	10.1007/978-3-642-80353-6_30	Bickert and Wefer (1996)
GeoB1117_2	10.1594/PANGAEA.713768 & 10.1594/PANGAEA.548402 & 10.1007/978-3-642-80353-6_30	Dittert (1998) Meinecke (1992) Bickert and Wefer (1996)
GeoB1118_3	10.1007/978-3-642-80353-6_30	Bickert and Wefer (1996)
GeoB1211_3	10.1007/978-3-642-80353-6_30	Bickert and Wefer (1996)
GeoB1214_1	10.1007/978-3-642-80353-6_30 & 10.1016/S0031-0182(96)00137-X	Bickert and Wefer (1996) Schmiedl and Mackensen (1997)
GeoB12605_3	10.1002/2013PA002555	Kuhnert et al. (2014)
GeoB12610_2	10.1002/jqs.2767	Rippert et al. (2015)
GeoB12615_4	10.5194/cp-10-293-2014	Romahn et al. (2014)
GeoB13731_1	10.1016/j.margeo.2013.04.009	Fink et al. (2013)
GeoB1505_2	10.1029/1999PA900027	Zabel et al. (1999)
GeoB16202_2	10.1002/2017PA003095 & 10.1002/2017PA003084 & 10.1029/2018PA003437	Voigt et al. (2017) Mulitza et al. (2017) Venancio et al. (2018)
GeoB16203_1	10.1002/2017PA003084 & 10.1002/2017PA003095	Mulitza et al. (2017) Voigt et al. (2017)
GeoB16205_4	10.1002/2017PA003084 & 10.1002/2017PA003095	Mulitza et al. (2017) Voigt et al. (2017)
GeoB16206_1	10.1016/j.epsl.2015.09.054 & 10.1002/2017PA003095	Zhang et al. (2015) Voigt et al. (2017)
GeoB16224_1	10.1016/j.epsl.2015.09.054 & 10.1002/2017PA003095 & 10.1016/j.quascirev.2017.12.005 & 10.1016/j.epsl.2019.05.006	Zhang et al. (2015) Voigt et al. (2017) Crivellari et al. (2018) Crivellari et al. (2019)
GeoB16602	10.1016/j.palaeo.2016.10.033 & 10.1016/j.epsl.2018.04.046 & 10.1038/s41561-018-0250-1	Liu et al. (2017) Huang et al. (2018) Cheng et al. (2018)
GeoB1710_3	10.1016/S0031-0182(96)00137-X & 10.1007/978-3-642-18917-3_26 & 10.1006/qres.1999.2040 & 10.1594/PANGAEA.57980	Schmiedl and Mackensen (1997) Volbers et al. (2003) Kirst et al. (1999) Müller (2001)

GeoB1711_4	10.1007/s003820050321 & 10.1016/S0031-0182(96)00136-8 & 10.1006/qres.1999.2040 & 10.1594/PANGAEA.143593	Vidal et al. (1999) Little et al. (1997) Kirst et al. (1999) Müller (2004a)
GeoB1720_2	10.1038/NGEO527	Dickson et al. (2009)
GeoB17426_3	10.1029/2019PA003832	Hollstein et al. (2020)
GeoB18131_1	10.1016/j.margeo.2019.02.007	Wang et al. (2019)
GeoB3004_1	10.1029/2006PA001284 & 10.1029/2004PA001044	Schmiedl and Mackensen (2006) Schmiedl and Leuschner (2005)
GeoB3104_1	10.1016/S0012-821X(99)00025-4 & 10.1006/qres.1998.1992	Arz et al. (1999b) Arz et al. (1998)
GeoB3129_1	10.1016/j.epsl.2005.11.012 & 10.1007/s003670050111	Weldeab et al. (2006) Arz et al. (1999a)
GeoB3202_1	10.1016/S0012-821X(99)00025-4	Arz et al. (1999b)
GeoB3302_1	10.1016/j.epsl.2008.04.043 & 10.1016/S0277-3791(02)00012-4 & 10.1029/2004PA001003 & 10.1006/qres.1998.2010	Mohtadi et al. (2008) Kim et al. (2002b) Mohtadi and Hebbeln (2004) Lamy et al. (1999)
GeoB3327_5	10.1029/2012PA002317	Ho et al. (2012)
GeoB3359_3	10.1016/j.epsl.2008.04.043 & 10.1016/j.yqres.2005.07.003	Mohtadi et al. (2008) Romero et al. (2006)
GeoB3808_6	10.1016/j.epsl.2015.03.004	Jonkers et al. (2015)
GeoB3910_2	10.1029/2006PA001391 & 10.1130/0091- 7613(2001)029<0239:MSCOSA>2.0.CO ;2	Jaeschke et al (2007) Arz et al. (2001)
GeoB3935_2	10.1016/S0967-0637(99)00076-X	Schlünz et al. (2000)
GeoB3938_1	10.5194/cp-10-843-2014 & 10.1016/S0967-0637(99)00076-X	Schlünz et al. (2014b) Schlünz et al. (2000)
GeoB4216_1	10.1016/S0967-0645(02)00101-7	Freudenthal et al. (2002)
GeoB4223_2	10.1016/s0967-0645(02)00102-9 & 10.1016/S0967-0645(02)00101-7	Henderiks et al. (2002) Freudenthal et al. (2002)
GeoB4240_2	10.1016/S0967-0645(02)00101-7	Freudenthal et al. (2002)
GeoB4411_2	10.5194/cp-10-843-2014	Govin et al. (2014b)
GeoB4901_8	10.1594/PANGAEA.66799 & 10.1016/j.margeo.2012.06.007	Adegbie (2001) Kallweit et al. (2012)
GeoB4905_4	10.1130/G21874.1 & 10.1016/S0031- 0182(03)00474-7	Weldeab et al. (2005) Adegbie et al. (2003)

GeoB5844_2	10.1016/j.quascirev.2006.07.016 & 10.1029/2002PA000864	Arz et al. (2007) Arz et al. (2003)
GeoB5901_2	10.1016/j.quascirev.2020.106220 & 10.1016/j.quascirev.2004.08.010 & 10.5194/cp-15-617-2019	Schirrmacher et al. (2020) Kim et al. (2004) Schirrmacher et al. (2019)
GeoB6211_2	10.1130/G24979A.1 & 10.1002/2014PA002677 & 10.1016/j.palaeo.2013.12.005 & 10.5194/cp-11-915-2015 & 10.1016/j.palaeo.2012.12.022	Chiessi et al. (2008) Voigt et al. (2015) Chiessi et al. (2014) Chiessi et al. (2015) Razik et al. (2013)
GeoB6518_1	10.1594/PANGAEA.135708 & 10.1038/nature03945 & 10.1016/j.gca.2012.01.024	Müller (2004b) Schefuss et al (2005) Rampen et al. (2012)
GeoB7010_2	10.5194/cp-10-843-2014	Govin et al. (2014b)
GeoB7011_1	10.5194/cp-10-843-2014	Govin et al. (2014b)
GeoB7165_1	10.1016/j.epsl.2008.04.043	Mohtadi et al. (2008)
GeoB7186_3	10.1016/j.quascirev.2006.12.008	Mohtadi et al. (2007)
GeoB7702_3	10.1029/2009PA001740	Castañeda et al. (2010)
GeoB7920_2	10.1038/ngeo289	Tjallingii et al. (2008)
GeoB7926_2	10.1016/j.quascirev.2014.04.027 & 10.1016/j.epsl.2012.05.018 & 10.1029/2008PA001601	McKay et al. (2014) Kim et al. (2012) Romero et al. (2008)
GeoB8331_4	10.1016/j.quaint.2015.10.017 & 10.2113/gssajg.110.2-3.327 & 10.1029/2010GL044353	Hahn et al. (2016) Herbert and Compton (2007) Leduc et al. (2010)
GeoB9307_3	10.1038/nature10685	Schefuss et al. (2011)
GeoB9508_5	10.1029/2008PA001637 & 10.1029/2009GL039687 & 10.1029/2010GL046070 & 10.1016/j.gloplacha.2013.03.007	Mulitza et al. (2008) Niedermeyer et al. (2009) Zarriess et al. (2011) Bouimetarhan et al. (2013)
GeoB9510_1	10.1029/2018PA003359	Völpel et al. (2019)
GeoB9512_5	10.1029/2018PA003359	Völpel et al. (2019)

523

GeoB9513_3	10.1029/2018PA003359	Völpel et al. (2019)
GeoB9526_5	10.1029/2010PA001944 & 10.1029/2010GL046070 & 10.1016/j.marmicro.2010.06.001	Zarriess and Mackensen (2011) Zarriess et al. (2011) Zarriess and Mackensen (2010)
GeoB9528_3	10.1073/pnas.0905771106 & 10.1016/j.epsl.2010.10.031 &	Castañeda et al. (2009) Hull et al. (2011)

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GeoTu_SL148	10.1016/j.palaeo.2007.01.004 & 10.1594/PANGAEA.701637	Ehrmann et al. (2007) Kuhnt et al. (2008)
GiK18515_3	10.1016/j.quascirev.2016.10.018	Schröder et al. (2016)
H214	10.1029/2004PA001088	Samson et al. (2005)
HLY02_02_17	10.1016/j.dsr2.2005.07.004 & 10.1029/2005PA001205	Cook et al. (2005) Brunelle et al. (2007)
HM79_4	10.1029/92PA01651 & 10.1029/2002PA000780	Karpuz and Jansen (1992) Dolven et al. (2002)
HM79_4_6	10.1029/92PA01651	Karpuz and Jansen (1992)
HU90_013_013	10.2312/reports-ifg.2001.13 & 10.1139/e94-007	Vogelsang et al. (2001) Hillaire-Marcel et al. (1994)
HU91_045_093	10.1144/jgs2013-097 & 10.1029/2011PA002155	Hoogakker et al. (2015) Hoogakker et al. (2011)
HYIV2015_B9	10.1029/2018GL078568	Li et al. (2018)
IOW225514	10.1191/0959683603hl634rp	Emeis et al. (2003)
IOW225517	10.1191/0959683603hl634rp	Emeis et al. (2003)
JM07_015	10.1002/jqs.2748 & 10.1111/bor.12282	Sternal et al. (2014) Telesiński et al. (2018)
JM96_1225_1_GC	10.1029/2001PA000632	Hagen and Hald (2002)
JM96_1225_2_GC	10.1029/2001PA000632	Hagen and Hald (2002)
JR244_GC528	10.1073/pnas.1511252113 & 10.1016/j.epsl.2017.07.004	Roberts et al. (2016) Roberts et al. (2017)
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KF13	10.3289/GEOMAR_REP_73_1998	Richter (1998)
KF16	10.1029/2012PA002281 & 10.5194/cp-13-333-2017 & 10.1002/2014PA002637 & 10.1016/j.epsl.2015.05.009	Schwab et al. (2012) Repschläger et al. (2017) Repschläger et al. (2015b) Repschl√§ger et al. (2015a)
KH94_3_LM_8	10.1002/jqs.843	Oba and Murayama (2004)
KNR110_50	10.1029/PA003i003p00361	Sarnthein et al. (1988)
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https://doi.org/10.5194/essd-2025-599
Preprint. Discussion started: 9 October 2025

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KNR159_42	10.1029/2004PA001021	Curry and Oppo (2005)
KNR159_5_36	10.1130/G25080A.1 & 10.1029/1999pa000436 & 10.1029/2004PA001021 & 10.1130/g25080a.1	Carlson et al. (2008) Oppo and Horowitz (2000) Curry and Oppo (2005) Carlson et al. (2008)
KNR166_2_1	10.1029/2008PA001717	Lynch-Stieglitz et al. (2009)
KNR166_2_105	10.1029/2008PA001717	Lynch-Stieglitz et al. (2009)
KNR166_2_106	10.1029/2008PA001717	Lynch-Stieglitz et al. (2009)
KNR166_2_113	10.1029/2008PA001717	Lynch-Stieglitz et al. (2009)
KNR166_2_119	10.1029/2008PA001717	Lynch-Stieglitz et al. (2009)
KNR166_2_127	10.1029/2008PA001717	Lynch-Stieglitz et al. (2009)
KNR166_2_135	10.1029/2008PA001717	Lynch-Stieglitz et al. (2009)
KNR166_2_2	10.1029/2008PA001717	Lynch-Stieglitz et al. (2009)
KNR166_2_51	10.1029/2008PA001717	Lynch-Stieglitz et al. (2009)
KNR195_5_CDH23	10.1002/2015PA002816	Bova et al. (2015)
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KNR31_GPC_5	10.1016/0198-0149(89)90032-0 & 10.1029/94jc00525 & 10.1029/1998PA900026	Keigwin and Jones (1989) Keigwin and Jones (1994) Keigwin and Boyle (1999)
KT05_7_PC_02	10.1016/j.quascirev.2008.12.009	Kawahata et al. (2009)
KT90_9_21	10.1002/jqs.843	Oba and Murayama (2004)
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KX973_21_2	10.1016/j.quascirev.2020.106361 & 10.1126/sciadv.abc0402 & 10.1038/s41586-022-05302-y &	Dang et al. (2020a) Dang et al. (2020b) Jian et al. (2022)

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Preprint. Discussion started: 9 October 2025

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LV28_42_4	10.1594/PANGAEA.59112 & 10.1029/2004PA001023	Kaiser (2002) Nürnberg and Tiedemann (2004)
LV29_114_3	10.5194/cp-10-591-2014 & 10.1002/palo.20014 & 10.1029/2012PA002292	Max et al. (2014a) Riethdorf et al. (2013a) Max et al. (2012)
LaPAS_KF02	10.1016/j.palaeo.2013.01.014	Pivel et al. (2013)
M125_445_7	10.1016/j.gloplacha.2020.103150 & 10.1029/2020GL087948	Hou et al. (2020a) Hou et al. (2020b)
M125_469_3	10.1016/j.quascirev.2019.105990 & 10.1029/2020PA003876	Campos et al. (2019) Campos et al. (2020)
M25_4_KL11	10.1016/S0031-0182(00)00053-5 & 10.1038/23432	Emeis et al. (2000) Allen et al. (1999)
M35003_4	10.3289/GEOMAR_REP_95_1999 & 10.1038/990069 & 10.2312/reports-ifg.2001.13	Hüls (1999) Rühlemann et al. (1999) Vogelsang et al. (2001)
M35027_1	10.3289/GEOMAR_REP_95_1999	Hüls (1999)
M39_008	10.1029/2000PA000502 & 10.2312/reports-ifg.2001.14	Cacho et al. (2001) Löwemark (2001)
M44_1_KL71	10.1016/S0031-0182(02)00596-5	Sperling et al. (2003)
M75_3_137_3	10.1002/palo.20053	Wang et al. (2013)
M77_2_056_5	10.1016/j.quascirev.2013.06.021 & 10.1002/2014PA002706	Mollier-Vogel et al. (2013) Nürnberg et al. (2015)
M77_2_059_1	10.1016/j.quascirev.2013.06.021 & 10.1002/2014PA002706	Mollier-Vogel et al. (2013) Nürnberg et al. (2015)
M78_1_235_1	10.1016/j.epsl.2017.01.030 & 10.1130/G35562.1 & 10.1016/j.gloplacha.2017.11.008 & 10.1029/2018PA003376	Poggemann et al. (2017) Hoffmann et al. (2014) Bahr et al. (2018) Reißig et al. (2019)
MD01_2378	10.1016/j.epsl.2010.12.021 & 10.1029/2004PA001094 & 10.1016/j.marmicro.2005.09.001 & 10.1029/2006PA001278 & 10.1016/j.marmicro.2007.10.002 & 10.1016/j.epsl.2008.06.029 &	Sarnthein et al. (2011) Holbourn et al. (2005) Kawamura et al. (2006) Xu et al. (2006) Dürkop et al. (2008) Xu et al. (2008)

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MD01_2386	10.1073/pnas.1915510117	Jian et al. (2020)
MD01_2390	10.1016/j.quascirev.2007.12.003	Steinke et al. (2008)
MD01_2412	10.1016/j.gloplacha.2006.01.012 & 10.1016/j.gloplacha.2006.01.010	Sakamoto et al. (2006) Harada et al. (2006)
MD01_2415	10.1029/2004PA001023	Nürnberg and Tiedemann (2004)
MD01_2416	10.2458/azu_rc.57.17916 & 10.5194/cp-9-2595-2013 & 10.1016/j.quascirev.2004.08.008 & 10.1029/2007PA001513 & 10.1038/s41561-018-0108-6	Sarnthein et al. (2015) Sarnthein et al. (2013) Sarnthein et al. (2004) Gebhardt et al. (2008) Gray et al. (2018)
MD01_2421	10.1002/jqs.843 & 10.1130/G25667A.1 & 10.1029/2004GL021903 & 10.1016/j.gloplacha.2006.05.002	Oba and Murayama (2004) Weinelt (1993) Yamamoto et al. (2005) Oba et al. (2006)
MD02_2488	10.1029/2008PA001603 & 10.5194/cp-8-483-2012	Govin et al. (2009) Govin et al. (2012)
MD02_2489	10.1029/2007PA001513	Gebhardt et al. (2008)
MD02_2496	10.1016/j.quascirev.2008.01.013 & 10.1016/j.epsl.2014.06.026 & 10.1002/2013PA002581	Cosma et al. (2008) Taylor et al. (2014) Chang et al. (2014)
MD02_2529	10.1038/nature05578	Leduc et al. (2007)
MD02_2550C 2	10.1029/2005PA001243 & 10.1029/2010PA001928	LoDico et al. (2006) Williams et al. (2010)
MD02_2551	10.1029/2005pa001186 & 10.1029/2005PA001186	Hill et al. (2006) Hill et al. (2006)
MD02_2575	10.1038/ngeo277 & 10.1016/j.epsl.2008.04.051	Ziegler et al. (2008) Nürnberg et al. (2008)
MD02_2589	10.1029/2006PA001407 & 10.1029/2007PA001511	Molyneux et al. (2007) Diz et al. (2007)
MD02_2594	10.1029/2009PA001879	Martínez-Méndez et al. (2010)
MD03_2607	10.1016/j.palaeo.2012.08.013 & 10.1002/palo.20035 & 10.1038/ngeo1856	Lopes dos Santos et al. (2012) Lopes dos Santos et al. (2013b) Lopes dos Santos et al. (2013a)
MD03_2611G	10.1594/PANGAEA.911840 & 10.1594/PANGAEA.923026 & 10.1016/j.quascirev.2017.11.033 & 10.1016/j.quascirev.2009.04.007 & 10.1016/j.epsl.2006.12.019 & 10.1017/qua.2021.12 &	Schneider et al. (2020) Moros and De Deckker (2020) Perner et al. (2018) Moros et al. (2009) Gingele et al. (2007) Moros et al. (2021)

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MD03_2697	10.1016/j.marmicro.2006.07.006 & 10.1016/j.quascirev.2014.09.001 & 10.1029/2009GC002398	Naughton et al. (2007) Salgueiro et al. (2014) Eynaud et al. (2009)
MD03_2707	10.1126/science.1140461	Weldeab et al. (2007)
MD05_2896	10.1016/j.yqres.2014.12.003 & 10.1002/2013PA002578 & 10.1016/j.palaeo.2010.04.005 & 10.1016/j.quascirev.2016.04.009	Dong et al. (2015) Wan and Jian (2014) Tian et al. (2010) Wang et al. (2016)
MD05_2897	10.1016/j.yqres.2014.12.003 & 10.1016/j.gloplacha.2012.06.003 & 10.1016/j.quascirev.2016.04.009	Dong et al. (2015) Huang and Tian (2012) Wang et al. (2016)
MD05_2904	10.3799/dqkx.2010.067 & 10.1016/j.gloplacha.2011.06.006	Ge et al. (2010) Steinke et al. (2011)
MD05_2920	10.1016/j.quascirev.2013.12.018 & 10.1016/j.quascirev.2011.09.016	Tachikawa et al. (2014) Tachikawa et al. (2011)
MD05_2925	10.5194/cp-10-2253-2014 & 10.1038/s41598-017-04031-x & 10.1016/j.quascirev.2022.107756 & 10.1038/ncomms10018	Lo et al. (2014) Lo et al. (2017) Lo et al. (2022) Liu et al. (2015)
MD06_2986	10.1002/2014PA002727	Ronge et al. (2015)
MD06_2990	10.1002/2014PA002727	Ronge et al. (2015)
MD06_3018	10.1029/2009PA001755 & 10.1029/2010PA002019	Russon et al. (2009) Russon et al. (2011)
MD06_3047B	10.1016/j.palaeo.2017.12.039	Jia et al. (2018)
MD06_3067	10.1029/2010PA001966	Bolliet et al. (2011)
MD06_3075	10.1002/2013PA002599	Fraser et al. (2014)
MD07_3076	10.1126/science.1183627 & 10.1016/j.epsl.2014.11.051 & 10.1038/ncomms11539 & 10.1029/2010PA002007 & 10.1073/pnas.1511252113	Skinner et al. (2010) Gottschalk et al. (2015) Gottschalk et al. (2016a) Waelbroeck et al. (2011) Roberts et al. (2016)
MD07_3077	10.1002/2016PA003029 & 10.1016/j.quascirev.2019.106067	Gottschalk et al. (2016b) Gottschalk et al. (2020)
MD07_3128	10.1029/2010PA002049	Caniupán et al. (2011)
MD10_3340	10.1126/sciadv.abc0402 & 10.1038/s41586-022-05302-y & 10.1002/2014GC005550	Dang et al. (2020b) Jian et al. (2022) Dang et al. (2015)
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https://doi.org/10.5194/essd-2025-599
Preprint. Discussion started: 9 October 2025

Open Access Earth System Science Data Discussions

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MD77_194	10.1029/PA003i003p00361 & 10.1016/S0277-3791(97)00099-1 & 10.2312/reports-gpi.1989.27	Sarnthein et al. (1988) Sonzogni et al. (1998) Sirocko (1989)
MD79_254	10.25921/9xvw-pr91 & 10.1029/PA003i003p00361	Duplessy (1996) Sarnthein et al. (1988)
MD79_257	10.1029/2006GC001514 & 10.1016/S0277-3791(97)00099-1 & 10.1016/0012-821X(91)90147-A	Levi et al. (2007) Sonzogni et al. (1998) Duplessy et al. (1991)
MD84_527	10.1029/PA004i006p00629 & 10.1029/PA003i003p00361 & 10.1029/92PA00709 & 10.1029/PA003i003p00343	Labracherie et al. (1989) Sarnthein et al. (1988) Pichon et al. (1992) Duplessy et al. (1988)
MD84_551	10.1029/PA004i006p00629 & 10.1029/92PA00709	Labracherie et al. (1989) Pichon et al. (1992)
MD88_770	10.1029/95PA02255	Labeyrie et al. (1996)
MD95_2002	10.1016/S0012-821X(01)00332-6 & 10.1130/0091- 7613(2000)28<123:WTNAHE>2.0.CO;2 & 10.1016/S0025-3227(02)00276-1 & 10.1029/2012GL052100 & 10.1016/j.palaeo.2016.12.031	Zaragosi et al. (2001) Grousset et al. (2000) Auffret et al. (2002) Eynaud et al. (2012) Zumaque et al. (2017)
MD95_2010	10.1038/46753 & 10.1029/158GM20 & 10.5194/cp-8-483-2012	Dokken and Jansen (1999) Risebrobakken et al. (2005) Govin et al. (2012)
MD95_2015	10.1016/S0012-821X(00)00113-8 & 10.1016/S0277-3791(01)00105-6	Giraudeau et al. (2000) Marchal et al. (2002)
MD95_2024	10.1029/2011PA002160 & 10.1029/2011PA002155 & 10.1144/jgs2013-097 & 10.1029/2000PA000560	Korte and Hesselbo (2011) Hoogakker et al. (2011) Hoogakker et al. (2015) Weber et al. (2001)
MD95_2039	10.1016/S0012-821X(98)00265-9 & 10.1016/j.quascirev.2014.09.001 & 10.1029/2009GC002398 & 10.1016/S0921-8181(02)00197-2	Thomson et al. (1999) Salgueiro et al. (2014) Eynaud et al. (2009) Schönfeld et al. (2003)
MD95_2040	10.1029/2010GM001021 & 10.1016/S0025-3227(03)00046-X & 10.1016/S0031-0182(01)00444-8 & 10.1029/2009GC002605 & 10.1016/S0012-821X(02)00787-2 & 10.1016/S0921-8181(02)00197-2	Voelker and de Abreu (2011a) de Abreu et al. (2003) Pailler and Bard (2002) Voelker et al. (2009) Moreno et al. (2002) Schönfeld et al. (2003)

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Preprint. Discussion started: 9 October 2025

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MD95_2042	10.1029/2000PA000513 & 10.1016/S0031-0182(01)00444-8 & 10.1029/1998PA900027	Shackleton et al. (2000) Pailler and Bard (2002) Cayre et al. (1999)
MD95_2043	10.1016/j.quascirev.2006.10.004 & 10.1029/1999PA900044 & 10.1016/j.quascirev.2014.06.016	Cacho et al. (2006) Cacho et al. (1999) Martrat et al. (2014)
MD96_2048	10.1016/j.epsl.2016.06.049 & 10.5194/cp-7-1285-2011 & 10.1038/s41586-018-0309-6	Castañeda et al. (2016) Caley et al. (2011) Caley et al. (2018)
MD96_2098	10.1073/pnas.1214292110 & 10.1029/2004PA001001	Daniau et al. (2013) Pichevin et al. (2005)
MD97_2120	10.1038/nature03544 & 10.1029/2005PA001191 & 10.1126/science.1084451 & 10.1126/science.1102163	Sachs and Anderson (2005) Pahnke and Sachs (2006) Pahnke et al. (2003) Pahnke and Zahn (2005)
MD97_2121	10.1029/2005PA001191 & 10.1002/palo.20032 & 10.1016/j.palaeo.2007.08.013	Pahnke and Sachs (2006) Marr et al. (2013) Carter et al. (2008)
MD97_2125_ abovehiatus	10.1016/j.quascirev.2008.12.013	Tachikawa et al. (2009)
MD97_2125_ belowhiatus	10.1016/j.quascirev.2008.12.013	Tachikawa et al. (2009)
MD97_2138	10.1029/2006PA001269	de Garidel-Thoron et al. (2007)
MD97_2141_ abovehiatus	10.1029/2001GC000260 & 10.1029/2000PA000557 & 10.1029/2021PA004361	Oppo et al. (2003a) de Garidel-Thoron et al. (2001) Weiss et al. (2022)
MD97_2141_ belowhiatus	10.1029/2001GC000260 & 10.1029/2000PA000557 & 10.1029/2021PA004361	Oppo et al. (2003a) de Garidel-Thoron et al. (2001) Weiss et al. (2022)
MD97_2142	10.3319/TAO.2008.19.4.363(IMAGES) & 10.1016/S0031-0182(03)00389-4 & 10.1073/pnas.1701315114	Shiau et al. (2008) Chen et al. (2003) Ren et al. (2017)
MD97_2151	10.5194/cp-9-2777-2013 & 10.1016/j.palaeo.2005.11.033	Yamamoto et al. (2013) Zhao et al. (2006)
MD98_2160	10.1029/2006GL027234	Newton et al. (2006)
MD98_2161	10.1016/j.gloplacha.2013.08.017 & 10.1038/s41598-018-24055-1	Fan et al. (2013) Fan et al. (2018)
MD98_2162	10.1016/j.quascirev.2003.07.001 & 10.1038/s41586-022-05302-y	Visser et al. (2004) Jian et al. (2022)

MD98_2165	10.1016/j.epsl.2005.12.031 & 10.1029/2006GC001514	Waelbroeck et al. (2006) Levi et al. (2007)
MD98_2170	10.1126/science.1143791	Stott et al. (2007)
MD98_2176	10.1126/science.1143791 & 10.1038/nature02903	Stott et al. (2007) Stott et al. (2004)
MD98_2178	10.1016/j.gloplacha.2013.08.017 & 10.1038/s41598-018-24055-1	Fan et al. (2013) Fan et al. (2018)
MD98_2181	10.1029/2006PA001379 & 10.1126/science.1143791 & 10.1016/j.quascirev.2009.05.007 & 10.1126/science.1071627	Stott (2007) Stott et al. (2007) Saikku et al. (2009) Stott et al. (2002)
MD98_2188	10.1016/j.marmicro.2006.02.003 & 10.1029/2011GL050154	Lin et al. (2006) Dang et al. (2012)
MD99_2203	10.1029/2011PA002184	Cléroux et al. (2012)
MD99_2236	10.1016/j.quascirev.2014.10.022	Jennings et al. (2015)
MD99_2256	10.1016/j.marmicro.2010.08.002 & 10.1016/j.quascirev.2014.10.022	(Ólafsdóttir et al., 2010) (Jennings et al., 2015)
MD99_2281	10.5194/cp-11-1507-2015 & 10.1002/jqs.2601 & 10.5194/cp-8-1997-2012	Wary et al. (2015) Caulle et al. (2013) Zumaque et al. (2012)
MD99_2284	10.1002/palo.20042 & 10.1029/2011PA002117 & 10.1038/ngeo439	Dokken et al. (2013) Risebrobakken et al. (2011) Bakke et al. (2009)
MD99_2304	10.1016/j.quascirev.2004.08.006 & 10.1029/158GM20	Hald et al. (2004) Risebrobakken et al. (2005)
MD99_2331	10.1016/j.epsl.2009.05.001 & 10.1016/j.quascirev.2014.09.001 & 10.1029/2009GC002398	Naughton et al. (2009) Salgueiro et al. (2014) Eynaud et al. (2009)
MD99_2339	10.1016/j.epsl.2006.03.014 & 10.1029/2009GC002605 & 10.1029/2010GM001021	Voelker et al. (2006) Voelker et al. (2009) Voelker and de Abreu (2011a)
MD99_2343	10.1029/2004PA001051 & 10.1016/j.quaint.2007.06.016	Sierro et al. (2005) Frigola et al. (2008)
ME0005A_24 JC	10.1016/j.epsl.2009.12.030 & 10.1016/j.quascirev.2010.10.012 & 10.1038/nature05222	Kusch et al. (2010) Dubois et al. (2011) Kienast et al. (2006)
ME0005A_27 JC	10.1029/2006PA001357 & 10.1016/j.quascirev.2010.10.012	Kienast et al. (2007) Dubois et al. (2011)
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MR00_05_2P	10.1016/j.marmicro.2010.01.003	Koizumi and Yamamoto (2010)

https://doi.org/10.5194/essd-2025-599
Preprint. Discussion started: 9 October 2025

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MR99_04_2PC	10.1016/j.marmicro.2010.01.003	Koizumi and Yamamoto (2010)
MR99_04_3PC	10.1016/j.marmicro.2010.01.003	Koizumi and Yamamoto (2010)
MSM02_3_666_4	10.5194/cp-13-1717-2017	Bartels et al. (2017)
MSM02_3_739_3	10.1111/bor.12325	Bartels et al. (2018)
MSM05_5_712_1	10.1016/j.palaeo.2011.05.030 & 10.1126/science.1197397	Werner et al. (2011) Spielhagen et al. (2011)
MSM05_5_712_2	10.1002/palo.20028 & 10.1016/j.quascirev.2012.04.024 & 10.1016/j.epsl.2014.07.016	Werner et al. (2013) Müller et al. (2012) Müller and Stein (2014)
MSM05_5_723_2	10.1016/j.quascirev.2012.04.024 & 10.1016/j.quascirev.2015.09.007	Müller et al. (2012) Werner et al. (2016)
MV0502_4JC	10.1029/2008PA001661	Waddell et al. (2009)
NA87_22	10.1029/2008PA001696 & 10.1038/358485a0 & 10.2312/reports-ifg.2001.13	Gherardi et al. (2009) Duplessy et al. (1992) Vogelsang et al. (2001)
NEAP18K	10.1130/0091-7613(1999)027<0795:givfna>2.3.co;2 & 10.1029/1998pa900004	Chapman and Shackleton (1999) Cortijo et al. (1999)
NEAP_04K	10.1016/j.quascirev.2004.04.004 & 10.1029/2004GC000858	Hall et al. (2004) Rickaby and Elderfield (2005)
NGHP_01_17	10.1038/s41467-018-07076-2 & 10.1002/2014GC005586	Gebregiorgis et al. (2018) Ali et al. (2015)
OCE326_GGC30	10.1029/2006GL028495	Sachs (2007)
ODP1012	10.1126/science.1059209	Herbert et al. (2001)
ODP1016C	10.1016/j.quascirev.2006.07.014	Yamamoto et al. (2007)
ODP1020	10.2973/odp.proc.sr.167.206.2000 & 10.1029/98pa00069	Heusser et al. (2000) Herbert et al. (1998)
ODP1084B	10.1029/2004PA001049	Farmer et al. (2005)
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Preprint. Discussion started: 9 October 2025

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ODP807	10.1016/j.marmicro.2007.03.003 & 10.1002/2015PA002906 & 10.1016/j.gloplacha.2022.103945	Zhang et al. (2007) Du et al. (2016) Feng et al. (2022)
ODP846	10.1029/2002PA000877 & 10.2973/odp.proc.sr.138.160.1995 & 10.1126/science.1120395	Martínez et al. (2003) Mix et al. (1995a) Lawrence et al. (2006)
ODP849	10.2973/odp.proc.sr.138.120.1995	Mix et al. (1995b)
ODP980	10.1126/science.283.5404.971 & 10.1016/j.quascirev.2006.07.006 & 10.1029/1998PA900021 & 10.1038/422277b	McManus et al. (1999) Oppo et al. (2006) Ortiz et al. (1999) Oppo et al. (2003b)
ODP982	10.1029/1998PA900013 & 10.1029/2008pa001669	Venz et al. (1999) Lawrence et al. (2009)
ODP984C	10.1038/ngeo227 & 10.1130/G23455A & 10.1029/1998PA900021	Praetorius et al. (2008) Came et al. (2007) Ortiz et al. (1999)
ODP_677	10.1017/S0263593300020782	Shackleton et al. (1990)
OMEXII_9K_2	10.1016/j.epsl.2016.01.016 & 10.1016/S0012-821X(00)00068-6	Hendry et al. (2016) Hall and McCave (2000)
P178_15P	10.1038/ngeo2603	Tierney et al. (2016)
P7	10.1029/91PA02532 & 10.1029/pa003i002p00157	Pedersen et al. (1991) Pedersen et al. (1988)
PBBC_1	10.1130/G23507A.1	Richey et al. (2007)
PM9462_4	10.1016/S0921-8181(01)00116-3 & 10.2312/BzP_0281_1998	Bauch et al. (2001) Kunz-Pirrung (1998)
POS200_10_28_1	10.1016/S0025-3227(98)00062-0 & 10.1016/j.quascirev.2014.09.001	Abrantes et al. (1998) Salgueiro et al. (2014)
POS200_10_6_2	10.1016/S0031-0182(96)00135-6	Baas et al. (1997)
POS457_905_2	10.1029/2019GC008298	Mirzaloo et al. (2019)
POS457_909_2	10.1029/2019GC008298	Mirzaloo et al. (2019)
PS1388_3	10.1016/0025-3227(89)90068-6 & 10.1029/AR056p0349	Mackensen et al. (1989) Grobe and Mackensen (2013)
PS1730_2	10.2312/BzP_0241_1997	Nam (1997)

PS1878_3	10.5194/cp-10-123-2014 & 10.1111/bor.12045	Telesiński et al. (2014b) Telesiński et al. (2014a)
PS2082_1	10.1594/PANGAEA.50113 & 10.1594/PANGAEA.57592 & 10.1029/1998PA900020	Mackensen et al. (1994) Bohrmann (2005) Brathauer and Abelmann (1999)
PS2138_1	10.1111/j.1365-246X.2003.02115.x & 10.1016/S0025-3227(99)00106-1 & 10.1029/1999PA000454 & 10.1016/j.yqres.2003.07.008 & 10.1029/98PA01501	Nowaczyk et al. (2003) Knies et al. (2000) Wollenburg et al. (2001) Knies and Vogt (2003) Knies and Stein (1998)
PS2495_3	10.1016/S0921-8181(01)00102-3 & 10.1594/PANGAEA.55886 & 10.1029/2010PA001940 & 10.1594/PANGAEA.55890 & 10.1594/PANGAEA.55891 & 10.1594/PANGAEA.55893	Mackensen (2001) Niebler (2004a) Groeneveld and Chiessi (2011) Niebler (2004e) Niebler (2004d) Niebler (2004c)
PS2498_1	10.1594/PANGAEA.55887 & 10.1594/PANGAEA.55888 & 10.1594/PANGAEA.55889 & 10.1594/PANGAEA.55892 & 10.1016/S0921-8181(01)00102-3 & 10.1098/rsta.2013.0054	Niebler (2004b) Niebler (2004h) Niebler (2004g) Niebler (2004f) Mackensen (2001) Anderson et al. (2014)
PS75_056_1	10.1002/2016PA002932 & 10.1016/j.quascirev.2016.06.006	Ullermann et al. (2016) Benz et al. (2016)
PS75_059_2	10.1038/ncomms11487 & 10.1002/2016PA002932 & 10.1126/science.1245424	Ronge et al. (2016) Ullermann et al. (2016) Lamy et al. (2014)
PS75_160_1	10.1038/nature22995	Hillenbrand et al. (2017)
PS75_167_1	10.1038/nature22995	Hillenbrand et al. (2017)
R657	10.1029/97PA02982 & 10.1029/2001PA000640	Weaver et al. (1998) Sikes et al. (2002)
RAPiD_10_1P	10.1029/2009PA001833 & 10.1016/j.gloplacha.2010.06.003	Thornalley et al. (2010b) Thornalley et al. (2011)
RAPiD_12_1K	10.1038/nature07717	Thornalley et al. (2009)
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RAPiD_17_5P	10.1029/2009PA001833 & 10.1016/j.gloplacha.2010.06.003	Thornalley et al. (2010b) Thornalley et al. (2011)
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RC13_228	10.1594/PANGAEA.139596 & 10.1594/PANGAEA.51105 & 10.2312/reports-ifg.2001.13	Curry (2004a) Ruddiman and Farrell (1996a) Vogelsang et al. (2001)
RC13_229	10.1594/PANGAEA.139597 & 10.1594/PANGAEA.51106 & 10.1029/PA005i001p00043 & 10.1016/0012-821X(87)90183-X & 10.1029/93PA02199	Curry (2004b) Ruddiman and Farrell (1996b) Oppo et al. (1990) Oppo and Fairbanks (1987) Oppo and Rosenthal (1994)
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SK237_GC04	10.1016/j.epsl.2013.05.022	Saraswat et al. (2013)
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SO201_2_12KL	10.5194/cp-10-591-2014 & 10.1002/palo.20014 & 10.1029/2012PA002292	Max et al. (2014a) Riethdorf et al. (2013a) Max et al. (2012)
SO201_2_85	10.1002/palo.20014 & 10.5194/cp-9-1345-2013 & 10.5194/cp-10-591-2014 & 10.1029/2012PA002292 & 10.1130/G35879.1 & 10.1016/j.dsr2.2015.03.007	Riethdorf et al. (2013a) Riethdorf et al. (2013b) Max et al. (2014a) Max et al. (2014b) Riethdorf et al. (2016)
SO213_2_59_2	10.1016/j.epsl.2014.11.031	Tapia et al. (2015)
SO213_2_82_1	10.1038/ncomms11487 & 10.1002/2014PA002727	Ronge et al. (2016) Ronge et al. (2015)
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SU81_14	10.1016/0033-5894(89)90045-8	Bard et al. (1989)
SU81_18	10.25921/9xvw-pr91 & 10.1038/35089060 & 10.1016/0033-5894(89)90045-8 & 10.1126/science.289.5483.1321 & 10.2312/reports-ifg.2001.13	Duplessy (1996) Waelbroeck et al. (2001) Bard et al. (1989) Bard et al. (2000) Vogelsang et al. (2001)
SU90_03	10.1029/1998pa900004	Cortijo et al (1999)
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SU90_24	10.1016/S0012-821X(01)00561-1 & 10.1016/S0277-3791(01)00137-8 & 10.1029/98PA01792	Elliot et al. (2001) Elliot et al. (2002) Elliot et al. (1998)
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V19_27	10.1029/2000PA000538 & 10.1029/2003PA000894 & 10.1029/2008PA001593	Lyle et al. (2002) Koutavas and Lynch-Stieglitz (2003) Koutavas and Sachs (2008)
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V22_108	10.1029/91PA02477	Charles et al. (1991)
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V28_122	10.1017/S0033822200044234 & 10.1016/0012-821X(87)90183-X & 10.1038/nature02346	Broecker et al. (1988a) Oppo and Fairbanks (1987) Schmidt et al. (2004)
V28_127	10.1594/PANGAEA.358950 & 10.1594/PANGAEA.51306 & 10.1029/PA005i003p00277 & 10.2312/reports-ifg.2001.13 & 10.1016/0033-5894(84)90098-X	CLIMAP Project Members (2006c) Ruddiman and Farrell (1996e) Oppo and Fairbanks (1990) Vogelsang et al. (2001) Cline et al. (1984)
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V29_202	10.1029/95PA02089	Oppo and Lehman (1995)
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V30_49	10.1594/PANGAEA.51370 & 10.1029/PA003i003p00361 & 10.2312/reports-ifg.2001.13	Ruddiman and Farrell (1996f) Sarnthein et al. (1988) Vogelsang et al. (2001)
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