QUIGS-IFG Virtual Meeting on Chronologies of Late Pleistocene Terminations (T5-0)

May 17th and 19th 2021

INQUA Palaeoclimate Commission (PALCOM) Multi-year Project on Past Glacial Terminations

T5-0 Steering Committee:

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Session 1. Monday, May 17th, 2021, 12:00-3:00 pm PDT*

Zoom Link
https://ucsb.zoom.us/j/89884485731?pwd=VTBsbVVZLzl3MHZIRWovRW5tZVNkdz09
Meeting ID: 898 8448 5731
Passcode: Chronology

* Pacific Daylight Time (PDT) → please convert yourself

SCHEDULE	TIME (PDT)*	SPEAKER	TALK TITLE
INTRODUCTION	12:00-12:10 PM	L. Lisiecki	Opening Remarks
BLOCK 1	12:10-12:25	J. Rae	New constraints on deglaciation, reservoir ages, and rapid climate change in the North Atlantic from regionally consistent chronologies
	12:25-12:40	T. Lee	Multiproxy Bayesian Age Models with BIGMACS
	12:40-12:55	D. Rand	Atlantic Benthic $\delta^{18}O$ Lags During Termination 1
QUESTIONS	12:55-1:10		
BREAK	1:10-1:30		
BLOCK 2	1:30-1:45	J. Muglia	Ocean Circulation and Carbon Cycling: A stable isotope database of the last deglaciation
	1:45-2:00	L. Tarasov	A North/South comparison of T2 and T1 from approximate Bayesian calibrations of glaciological models for the Greenland and Antarctic ice sheets
	2:00-2:15	D. Lowry	Model-proxy comparison of Antarctic Ice Sheet retreat during Termination 2 and implications of future change
QUESTIONS	2:15-2:30		
BREAK-OUT ROOMS FOR DISCUSSION + WRAP-UP	2:30-3:00		

Session 2. Wednesday, May 19th, 2021, 7:00-11:30 am PDT*

Zoom Link: https://ethz.zoom.us/j/63617393042?pwd=N2JYRG9DbmE2N1dJV0ZtUEpvb0lQdz09

Meeting ID: 636 1739 3042

Passcode: Chronology

*Pacific Daylight Time (PDT) → please convert yourself

SCHEDULE	TIME (PDT)*	SPEAKER	TALK TITLE
INTRODUCTION	7:00-7:10 AM	H. Stoll	Opening Remarks
BLOCK 1	7:10-7:25	E. Capron	Sequence of events from the onset to the demise of the Last Interglacial (140-105 ka): how to address chronologies in paleoclimatic archives?
	7:25-7:40	E. Legrain	Building a coherent temporal framework for a new multi-archive climate synthesis over Termination III and Marine Isotopic Stage 7
	7:40-7:55	M. Mas e Braga	Improving data-model comparisons of ice surface thinning in regions of complex topography
	7:55-8:10	L. Silva	Centennially resolved atmospheric CO2 concentrations during T2 from the EPICA Dome C ice core
QUESTIONS	8:10-8:25		
BLOCK 2	8:25-8:40	O. Pollard	Quantifying Uncertainty in the North Sea Regional Last Interglacial Highstand Driven by the MIS-6 Deglaciation
	8:40-8:55	C. Hillaire-Marcel	The specific response of the Arctic Ocean to orbital forcing and the sea-level jocker
	8:55-9:10	F. Parrenin	Amplitude and phase modulation of glacial cycles from a conceptual model
QUESTIONS	9:10-9:20		
BREAK	9:20-9:50		
BLOCK 3	9:50-10:05	M. Brandon	Exceptionally high biosphere productivity during Termination V and MIS 11, relation with local productivity records and their contribution to the atmospheric CO2 variations
	10:05-10:20	T. Pollard	Rates of deglacial warming in southern Europe through Terminations IV and V constrained by speleothem-based palaeotemperature reconstructions
	10:20-10:35	Y. Krüger	Glacial-Interglacial temperature changes in the tropical west Pacific across Terminations V and IV based on fluid inclusion microthermometry in speleothems
	10:35-10:50	D. d'Olier + G. Hes	New Iberian Margin pollen record to constrain the climate evolution of Termination V
QUESTIONS	10:50-11:00		
BREAK-OUT ROOMS FOR DISCUSSION + WRAP-UP	11:00-11:30		

Meeting Abstracts

Monday, 17 May 2021

New constraints on deglaciation, reservoir ages, and rapid climate change in the North Atlantic from regionally consistent chronologies

James Rae*, Andrea Burke, Rosanna Greenop, Rhian Rees-Owen, Paula Reimer, Tim Heaton

Paleoclimate records from the North Atlantic show some of the most iconic signals of abrupt climate change during the ice ages, but variable reservoir ages and regionally distinct paleoclimate signals complicate chronologies. Here we present a stack of North Atlantic surface radiocarbon reservoir ages over the past 40,000 years, using new synchronized age models from over 20 sediment cores refined with thorium normalization between tie-points. This stack shows consistent and large reservoir age increases of more than 1000 years from the LGM into HS1, dropping abruptly back to approximately modern reservoir ages before the onset of the Bolling-Allerod. We use the intermediate complexity earth system model cGENIE to investigate the potential drivers of these reservoir age changes. We find that sea ice, circulation and CO_2 all play important roles in setting the reservoir age. We use these coherently dated records to revisit the sequence and timing of climatic events during HS1 and the last deglaciation, and show that Laurentide Heinrich Events are a response to stadial conditions, rather than their root cause.

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Multiproxy Bayesian Age Models with BIGMACS

Taehee Lee*, Lorraine Lisiecki, Devin Rand, Geoffrey Gebbie, Charles Lawrence

We introduce a new algorithm for multiple signal alignment and its practical application to paleoceanography, Bayesian Inference Gaussian Process Multiproxy Alignment of Continuous Signals (BIGMACS, [Lee et al., in prep]). BIGMACS is designed to infer ages from radiocarbon (an age proxy) and benthic d18O (a synchronizing proxy) simultaneously by incorporating calendar ages into the alignment process. A hybrid of particle smoothing and Markov-chain Monte Carlo algorithms probabilistically aligns benthic d18O signals to a stack by sampling the alignments continuously. The stack is iteratively updated as the integration of Gaussian process regression over the sampled alignments. We present two multiproxy, probabilistic regional stacks generated in BIGMACS, an equatorial Pacific stack of four cores (TR163-22, TR163-31, V19-28 and V19-30) and a deep northeast Atlantic stack of five cores (GeoB7920-2. GeoB9508-5, GeoB9526-5, MD95-2042 and MD99-2334). We demonstrate how BIGMACS leverages information from both radiocarbon and benthic d18O alignment to reduce age uncertainty in the regional stacks and describe differences in the timing of d18O change between the two stacks across the last glacial termination (T1). We also show how BIGMACS can be used for multiproxy alignment of an individual core to a regional stack if the core and stack sample the same water mass composition through time.

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Atlantic Benthic $\delta^{18}O$ Lags During Termination 1

*Devin Rand, Lorraine Lisiecki, Taehee Lee, Geoffrey Gebbie, Charles Lawrence

Recent studies have identified lags between Atlantic benthic $\delta^{18}O$ records during Termination 1 (T1) which can introduce age errors during stratigraphic alignment; however, previous studies did not evaluate the statistical significance of these lags or map their spatial extent. Here, we present timeseries of $\delta^{18}O$ lags and their uncertainties across T1 for 36 Atlantic cores between latitudes of 38 N and 30 S. We measure $\delta^{18}O$ leads and lags as the difference between a core's radiocarbon age model and an age model based on $\delta^{18}O$ stratigraphic alignment to an Atlantic stack. Probability distributions for the radiocarbon and $\delta^{18}O$ age models are constructed using new Bayesian software BIGMACS (Lee et al., in prep). By subtracting sampled radiocarbon age models from $\delta^{18}O$ age model samples, we generate timeseries of $\delta^{18}O$ lags and their uncertainties. Leads and lags are reported relative to a seven core Atlantic stack, which represents the average Atlantic signal. Statistically significant leads up to 2.4 kyr (95% CI: 1.6 – 3.4 kyr) are observed at the Demerara Rise between depths of 1 and 1.5 km. In contrast, lags up to 2.8 kyr (95% CI: 1.7 – 4.2 kyr) are observed at the Brazil Margin below 2500 m. Statistically significant lags are less common in the East Atlantic. These results suggest that $\delta^{18}O$-aligned age models are likely insufficient to reconstruct the timing of millennial scale climate events during glacial terminations. Potential mechanisms that may generate $\delta^{18}O$ lags include: (1) changes in the rate of overturning circulation, (2) asynchronous changes in end-member water mass properties, and (3) water mass boundary shifts. Idealized experiments using an ocean circulation inverse model suggest that a combination of all three factors explains the observed lags during T1.

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Ocean Circulation and Carbon Cycling: A stable isotope database of the last deglaciation

Juan Muglia*, Lorraine Lisiecki, Alan Mix, Stefan Mulitza, Andreas Schmittner, Janne Repschläger, Elisabeth Sikes

The Ocean Carbon and Cycling Project (OC3) project aims to create a global database of deglacial stable isotope data with high resolution age models. Numerous sites exist with these characteristics, but most of them have been reported independently from one another, and measured by different scientific groups and laboratories. Isotope data may have been subject to corrections, the species sampled differ among cores, and the methods to calculate age models may not be compatible among different sites. To create a global database of the deglacial period, these aspects need to be correctly documented, and age models need to be standardized. In this talk we describe the work in progress regarding the OC3 database, and discuss future goals.

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A North/South comparison of T2 and T1 from approximate Bayesian calibrations of glaciological models for the Greenland and Antarctic ice sheets

Lev Tarasov*, Benoit Lecavalier, Glenn Milne, Dave Roberts, Sarah Woodroffe

How do T2 and T1 compare for these two ice sheets? To address this we first step back and address a more basic question. What are the of not implausible T2 and T1 chronologies given limited constraints, uncertainties in climate, and the physics of ice and ice loss?

We address this with a combination of a glaciological model, paleo data, and approximate Bayesian inference. The model is 3D Glacial Systems Model (GSM), that includes various climate representations (including a coupled 2D energy balance climate model for Greenland), and a host of relevant processes. We use a large of constraint data, including: RSL, present-day ice sheet configuration, ice core basal temperatures, cosmogenic dates, marine C14 dates, and Eemian preservation of Dye3 and Camp Century ice. The Bayesian inference includes carefully specified error models and MCMC sampling with Bayesian artificial neural network emulators of the GSM to approximately deal with a 33 dimensional parameter space. Parameters address uncertainties in climate, earth rheology for GIA, basal drag, and marine ice loss.

We will present an analysis of over ten thousand GSM simulations for each ice sheet, with each simulation covering two full glacial cycles. *If there is any specific ice sheet characteristic you are interested in, let us know ahead of time, and we may include it in the presented analysis.*

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Model-proxy comparison of Antarctic Ice Sheet retreat during Termination 2 and implications of future change

Daniel Lowry*, Nick Golledge, Laurie Menviel

Termination 2 (T2, ~138 to 128 ka) precedes the warm Last Interglacial (LIG, ~129 to 116 ka), a period of time in which global sea levels were ~6 to 9 m higher than present (Dutton et al., 2015). The sea level contributions of individual ice sheets are poorly constrained through this interval, with our understanding limited by a lack of available records of both polar paleoclimate evolution and ice mass change. Here, we show a series of transient ice sheet model simulations of Antarctica to help resolve the sequence and controlling processes of deglacial ice sheet retreat during T2. The model results, which show strong agreement to near and far-field proxy reconstructions, indicate a maximum Antarctic LIG sea level contribution of 4 m at 126 ka, primarily from marine ice sheet instability in the Amundsen Sea sector of West Antarctica. Forward projection of the model under a current climate beyond present day predicts a similar retreat in this sector, with a long-term (4000-year) sea level commitment of 4 m, even without further greenhouse gas emissions. We discuss remaining uncertainties and planned ice sheet simulations to improve understanding of the role of meltwater feedbacks and solid Earth processes in Antarctic T2 retreat, as well as the LIG contribution of the Greenland ice sheet.

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Wednesday, 19 May 2021

Sequence of events from the onset to the demise of the Last Interglacial (140-105 ka): how to address chronologies in paleoclimatic archives?

Emilie Capron*, A. Govin, C. Tzedakis, S. Verheyden, B. Ghaleb, C. Hillaire-Marcel, G. St-Onge, J. S. Stoner, F. Bassinot, L. Bazin, T. Blunier, A. El Ouahabi, D. Genty, R. Gersonde, P. Jimenez-Amat, A. Landais, B. Martrat, V. Masson-Delmotte, M.-S. Seidenkrantz, D. Veres, C. Waelbroeck, R. Zahn.

The Last Interglacial (LIG) represents a precious case study to investigate the response of vulnerable components of the Earth system to polar warming. However, the scarcity of precise absolute age constraints in most archives during this time interval leads to the use of different reference chronologies and various strategies to align paleoclimatic records. Therefore, the investigation of the climatic sequence of events across the LIG remains limited.

Here, we review the strengths and limitations of the methods that are commonly used to date or define chronologies in various paleoclimatic archives (corals, speleothems, polar ice, marine sediments, lake sediments and peat sequences) for the time span encompassing the penultimate deglaciation, the LIG and its demise (~140-100 ka). In particular, we provide quantitative estimates of the associated absolute and relative age uncertainties.

Subsequently, we formulate recommendations on how to define at best absolute and relative chronologies. Future climate alignments should provide (1) a clear statement of climate hypotheses involved, (2) a detailed understanding of environmental parameters controlling selected tracers and (3) a careful evaluation of the synchronicity of aligned paleoclimatic records. We insist on the need to (1) systematically report quantitative estimates of relative and absolute age uncertainties, (2) assess the coherence of chronologies when comparing different records and (3) integrate these uncertainties in paleoclimatic interpretations and comparison with climate simulations.

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Building a coherent temporal framework for a new multi-archive climate synthesis over Termination III and Marine Isotopic Stage 7

Etienne Legrain*, Emilie Capron, Frédéric Parrenin

Marine Isotopic Stage 7 (~190-243 ka BP), is a past warm period of special interest e.g. (i) it follows the fastest deglaciation, Termination III, in the context of the last 800 ka (ii) the structure of MIS 7 is characterized by two warm periods separated by a cooler interval, and (iii) it took place during a context of strong orbital eccentricity. These specificities make MIS 7 one of the most misunderstood interglacials. In addition, mainly because aligning different paleoclimatic archives from different parts of the world is not trivial, a spatio-temporal picture of climatic changes across this time interval is difficult to obtain.

Here, we present the first global multi-archive synthesis focusing on Terminations III and MIS 7. We compiled sea surface temperature records from 52 marine sediment cores with a temporal resolution better than 4 ka and surface air temperature reconstructions from three Antarctic ice cores covering 190-260 ka. To decipher the sequence of climatic changes between the different records from different regions and different archives, we first need to define a common temporal framework for the different records. We are currently developing a first approach using the ice-core chronology AICC2012 as the reference chronology. Based on climatic assumptions, we align the high-latitude marine records (above 40°) onto AICC2012. Then, we define a reference high-latitude marine core for each oceanic basin to include low-latitude marine records (40°N-40°S) in our common temporal framework using benthic foraminifera $\delta^{18}O$ record alignments. In places, we also use planktonic foraminifera $\delta^{18}O$ to perform local climatic alignments. Based on a common chronostratigraphic framework and including records offering a multi-millennial-scale temporal resolution, our new synthesis will eventually allow to characterize the spatio-temporal structure of surface temperature changes across the globe during Termination III and the following MIS 7.

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Improving data-model comparisons of ice surface thinning in regions of complex topography

Martim Mas e Braga*, Jennifer CH Newall, Richard Selwyn Jones, Irina Rogozhina, Arjen P Stroeven

The reconstruction of past Antarctic ice sheet surface elevations and rates of ice thinning is commonly achieved through cosmogenic nuclide surface exposure dating. Exposure dating is often applied to vertical transects along nunataks, which typically present themselves in regions of strong surface relief and complex basal topography. In such regions, relating sample position and elevation on a nunatak to a meaningful contemporaneous ice surface elevation is not trivial. To develop meaningful “transfer functions”, ice modeling might help define expected patterns of ice thinning around obstacles. However, current-generation ice sheet models struggle to reproduce observed magnitudes and rates of ice thinning, hindering our ability to make accurate data-model inferences.

In this study, we use idealised modelling experiments to evaluate how the interaction between ice flow and nunatak perturbs ice surface elevations locally and regionally. By comparing a spatially-variable and locally refined mesh to coarser resolution regular meshes typically used in continent-wide ice sheet simulations, we assess to which degree the latter capture ice-surface responses around nunataks. We found that the ability of single, or several, nunataks to pond ice upstream, creates an exaggerated gradient in ice surface elevation. For several nunataks, the gradient scales inversely with glacier widths between the nunataks, mirroring drainage efficiency. Such gradients, while important from a cosmogenic nuclide sampling strategy and for inferring contemporaneous ice surface elevations from sample locations, are not captured by the coarser resolution simulations. This is because they neither capture a nunatak's shape properly nor resolve glacier widths below grid size, consequently overestimating elevation gradients and rates of ice thinning. To improve the integration of an ever-growing empirical database of cosmogenic nuclide constraints on former ice surface elevations with Antarctic paleoglaciological modeling of ice topography changes during terminations, there is a need to increase model resolution locally in regions of complex topography.

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Centennially resolved atmospheric CO_2 concentrations during T2 from the EPICA Dome C ice core

Lucas Silva*, Christoph Nehrbass-Ahles, Loïc Schmidely, Juhyeong Han, Jochen Schmitt, Hubertus Fischer, Thomas Stocker

Records of atmospheric CO_2 rise during the last 5 terminations are available for the EDC and Vostok ice cores at the millennial timescale (Lüthi et al., 2008; Petit et al., 1999). It has been recently discovered, however, that CO_2 can also undergo excursions at the centennial timescale, which urge the acquisition of overall better resolved records in order to inspect how frequently these events take place and under which conditions (Marcott et al., 2014; Nehrbass-Ahles et al., 2020). Here we present atmospheric CO_2 concentrations from a centennially resolved record using the EDC ice core, while looking in detail at other high-resolution records (Nehrbass-Ahles et al., 2020) that together span the last five terminations. The analysis reveals very similar rates of CO_2 rise even under different orbital configurations and hints at the possibility of short outbursts of CO_2 being a pervasive feature during a deglaciation.

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Quantifying Uncertainty in the North Sea Regional Last Interglacial Highstand Driven by the MIS-6 Deglaciation

Oliver G. Pollard*, Natasha L.M. Barlow, Lauren J. Gregoire, Natalya Gomez, Víctor Cartelle

The Last Interglacial (LIG) period (130 - 115 ka) was the last time in Earth's history that the Greenland and Antarctic ice sheets were smaller than those of today due, in part, to polar temperatures reaching 3 - 5 °C above pre-industrial values. Similar polar temperature increases are predicted in the coming decades and the LIG period could therefore help to shed light on ice sheet and sea level mechanisms in a warming world.

The North Sea region is a promising study site for the reconstruction of the magnitude and rate of LIG sea-level change as well as in the identification of individual ice sheet contributions. The impact of glacial isostatic adjustment (GIA) is particularly significant in this region due to its proximity to the former Eurasian ice sheet, which deglaciated during the penultimate deglaciation leading into the LIG. Interpretation of the LIG record is complicated by uncertainties in ongoing earth deformation, sea level evolution since the LIG, and in the geometry and evolution of the Eurasian ice sheet during the Penultimate Glacial Maximum (PGM).

We produce a range of plausible global ice sheet histories spanning the last 400 thousand years that vary in penultimate deglaciation characteristics and include a novel PGM Eurasian component constructed with the use of a simple ice sheet model (Gowan et al. 2016). We then employ a gravitationally consistent sea level model (Kendall et al. 2005) with a range of viscoelastic Earth structure models to calculate the global GIA response to each ice history and to infer which input parameters the North Sea LIG signal is most sensitive to. This work will improve our understanding of the GIA effects on near field relative sea level during previous interglacials and will enable a systematic quantification of uncertainties in LIG sea level in the North Sea.
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The specific response of the Arctic Ocean to orbital forcing and the sea-level jocker

Claude Hillaire-Marcel*, Anne de Vernal, Michel Crucifix

A recent revision of the climatostratigraphy of the Arctic Ocean demonstrates that its "interglacials" were of distinct amplitude and timing vs those of lower latitudes. We hypothesize here that the mean Summer season insolation, and not the June solstice peak, has been the primary driver of this specificity. Sea level has been the second important driver, as it governs the submergence of the Arctic Ocean shelves and the development of "sea-ice factories", as well as the flux of low-salinity Pacific waters through the shallow Bering Strait, thus the freshwater budget of the Arctic Ocean. Through feedbacks, such as the freshwater export that impacts the Atlantic Meridional Overturning Circulation, the Arctic Ocean may have triggered out-of-phase climate/ocean instabilities in the Northern Hemisphere, as it is likely to do it under its present freshening and reduction in sea-ice cover.

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Amplitude and phase modulation of glacial cycles from a conceptual model

Frédéric Parrenin*, Didier Paillard, Emilie Capron

The astronomical theory of climate, in which the orbital variations of the Earth are taken to drive the climate changes, explains many features of the paleoclimatic records. Nevertheless, the precise link between insolation variations and climatic changes during the Quaternary remains mysterious in several aspects. In particular, the largest sea level changes of the past million years occurred when insolation variations were minimal, like during stage 11, and vice versa like during stage 7. To explain these paradoxical amplitude modulations, we suggest here that deglaciations started when a combination of insolation and ice volume was large enough. To illustrate this new idea, we present a simple conceptual model that simulates the sea level curve of the past million years with very realistic amplitude modulations. This model also reproduces phase modulations, which were confirmed a posteriori by an accurate dating of the Dome Fuji ice core.

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Exceptionally high biosphere productivity during Termination V and MIS 11, relation with local productivity records and their contribution to the atmospheric CO_2 variations

Margaux Brandon*, Amaëlle Landais, Stéphanie Duchamp-Alphonse, Elisabeth Michel, Violaine Favre, Gulay Isguder, Léa Schmitz, Héloïse Abrial, Frédéric Prié, Nicolas Pige, Thomas Extier, Thomas Blunier, Franck Bassinot, Samuel Jaccard, Annachiara Bartolini

The Quaternary undergoes strong climatic variations during glacial-interglacial cycles, the fastest changes being registered during deglaciations, with large increases (up to 100 ppm) of atmospheric CO_2 concentration. A complete and quantitative explanation for these increases is still an open question since several biogeochemical fluxes are involved. Biological productivity is often invoked as one of the processes to trigger such changes. Understanding its impact over deglaciations is therefore essential. The use of proxies to unravel local paleoproductivity patterns in continent and ocean realms are very helpful but remain sparse and there is a crucial need for both global and local productivity records. Measurements of $\Delta^{17}O$ of O_2 in the air trapped in ice core can be used to provide indication of the evolution of the global gross primary productivity expressed in O_2 flux. In parallel, micropaleontological and geochemical data from marine sediments located in the Southern Ocean can be used to decipher the variations of the Biological Carbon Pump. Here we present the first high resolution record of $\Delta^{17}O$ of O_2 in the Antarctic EPICA Dome C ice core over Termination V (TV) and Marine Isotopic Stage (MIS) 11, used to reconstruct the global oxygen biosphere productivity over the last 445 ka. Our data show that biosphere productivity at the end of TV is 10 to 30 % higher than the younger terminations. Comparisons with coccolith, foraminifera, CaCO3 and CaXRF signals from marine core MD04-2718 located in the Indian sector of the Southern Ocean, together with published terrestrial and marine productivity records, show that both enhanced terrestrial productivity and CCP efficiency during TV and beginning of MIS 11 might have contributed to shape the 30 ka-long plateau of CO2 that characterizes this key period of the last 800,000 years.

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Rates of deglacial warming in southern Europe through Terminations IV and V constrained by speleothem-based palaeotemperature reconstructions

Timothy Pollard, Russell Drysdale*, Mathieu Daëron, John Hellstrom, Larry Edwards, Jon Woodhead, Xianglei Li, Nele Meckler, Hai Cheng, Henri Wong, Giovanni Zanchetta, Eleonora Regattieri, Ilaria Isola

The merging of speleothem and ocean-sediment records across glacial terminations can improve chronological constraints on termination timing. This can lead to advances in assessing astronomical and insolation controls on ice-age cycles, and provide useful information on rates of sea-level and temperature change across terminations. This approach rests on the presumption that the way in which speleothems and ocean records are linked - for example, through their oxygen-isotope patterns - is persistent through time. However, such persistence may not prevail over long time scales for a range of reasons. In this talk, we explore the potential for circumventing this problem by using speleothem palaeothermometry. We combine clumped-isotope-calibrated, high-resolution Mg/Ca variations in a subaqueous speleothem with multi-proxy stalagmite data from the same cave to explore the sequence of events through Terminations IV and V. The stalagmite data are anchored in time using a precise U-Th chronology. This chronology can be tied to the subaqueous palaeothermometer by synchronising their stable isotope profiles. The result is an absolutely dated proxy-temperature time series that can be correlated with sea-surface temperatures from the nearby North Atlantic. This allows us to calculate the rate of North Atlantic warming across T-IV and T-V and compare these rates with those from well-dated records of younger terminations.

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GLACIAL-INTERGLACIAL TEMPERATURE CHANGES IN THE TROPICAL WEST PACIFIC ACROSS TERMINATIONS V AND IV BASED ON FLUID INCLUSION MICROTHERMOMETRY IN SPELEOTHEMS

Y. Krüger*, A.N. Meckler, A. Fernandez, K.M. Cobb, J.F. Adkins

Speleothems, in particular stalagmites, are widely used as geological archives for reconstructing past climate variability. The possibility of absolute dating of the speleothems based on 238U–230Th decay back to 600 ka, and continuous growth over thousands of years makes speleothems particularly attractive for paleo-climate research. Speleothem formation temperature reflects variations of the mean annual air temperature outside the cave, but robust tools for reconstructing formation temperature have previously been lacking.

In the present study we used the density of former drip water preserved in microscopic fluid inclusions in the calcite matrix as a temperature proxy for determining stalagmite formation temperatures (Krüger et al., 2011). The density of these drip water relicts relates directly to the cave temperature at the time the inclusions have sealed off from the environment and can be deduced from measurements of the liquid–vapour homogenisation temperature Th using classical fluid inclusion microthermometry.

Using this paleo-thermometer, we have reconstructed a tropical cave temperature record based on stalagmite WR5 (Whiterock Cave, Northern Borneo; Meckler et al., 2012). We present a continuous record of cave temperatures spanning a 130 kyr time period ranging from 460 to 330 ka, which includes the glacial terminations V and IV. The reconstructed cave temperatures are mean values derived from 30 to 40 fluid inclusions along individual growth bands. 2sigma standard errors range between 0.23 and 0.47 °C. After correcting for altitude effects due to sea level changes (Spratt and Lisiecki, 2016) our cave temperature record reveals an amplitude of glacial–interglacial temperature changes in the tropical West Pacific of 3,8 ± 0,5 ºC between MIS 12 and MIS 11 and of 4,1 ± 0,5 ºC between MIS 10 and MIS 9. Temperature variations in our 130 kyr record correspond well to atmospheric CO2 concentrations (Bereiter et al., 2015). Although age model uncertainties do not permit assessing details in the relative timing of deglacial warming, the data yield the first estimates of tropical terrestrial temperature sensitivity to CO2 across several glacial-interglacial cycles.

This project was funded through FRINATEK grant 262353 from the Norwegian Research Council.

References: Y. Krüger et al., 2011. Chem. Geol., 289, 39–47. A.N. Meckler et al., 2012. Science, 336, 1301–1304. R.M. Spratt, L.E. Lisiecki, 2016. Clim. Past., 12, 1079-1092 B. Bereiter et al., 2015. http://ncdc.noaa.gov/paleo/study/17975

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New Iberian Margin pollen record to constrain the climate evolution of Termination V

Gabriel Hes*, Déborah d'Olier, María F. Sánchez Goñi, Nathaelle Bouttes

Among the 100kyr climatic cycles of the late Pleistocene, Termination V (~420 kyr) stands out for several reasons. At a global scale, interglacial periods after Termination V (TV) are characterized by higher atmospheric CO_2 concentrations, revealing a fundamental change in the climate system. In particular, MIS 11 is considered as a "super-interglacial" at high latitudes with very warm temperatures but cooler conditions at lower latitudes. From a cultural perspective, a diversification of Neanderthal tools and subsistence behaviors in western Europe is recorded during this interglacial. However, the driving mechanisms explaining the climate and cultural changes during TV remain unsolved.

For instance, climate models cannot fully represent the atmospheric CO_2 variation observed in paleoclimate data. Beside the important variation in oceanic circulation, there is increasing evidence that terrestrial biosphere may have played a key role in the global carbon cycle. A first attempt to explain the Iberian climate system and vegetation changes during TV has been published based on the U1385 pollen record. However, the low sedimentation rate observed doesn't allow sufficient resolution to establish a suitable climate reconstruction.

We propose a new high resolution (~500 yrs) pollen record in the Gulf of Cadiz (site U1386, 36°49.680 N; 7°45.320 W) for TV in order to 1) complete the regional climate evolution initiated by the U1385 record; and 2) enrich and construct a global pollen database for this period. This database will allow us to reconstruct changes in the composition and distribution of vegetation that may partly explain changes in atmospheric CO_2 concentration. Direct comparison of the resulting paleoclimate database to iLOVECLIM global simulations will serve to improve the model with the aim to better understand the role of terrestrial biosphere in the carbon cycle during TV.

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