The Ocean Floor Symposium
"SCENARIOS FOR WARMER WORLDS: LESSONS FROM THE PAST"

ABSTRACTS

Ocean Floor Symposium 2024
"Scenarios for Warmer Worlds: Lessons from the Past"

May 13 – May 16, 2024
at MARUM – Center for Marine Environmental Sciences,
University of Bremen

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The evolving carbon and climate relationship in the Palaeogene

E. Anagnostou[1], S. Khanolkar[1], A.-J. Drury[2], T. Westerhold[3], T. Babila[4], B. Ausin[5]

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The link between climate and CO_2 in Earth's history is not always straightforward, particularly during periods of multiple climatic and environmental changes, but atmospheric carbon dioxide (CO_2) plays an important part in determining climate on human and geological timescales. Using advancements in our understanding of the B proxies on foraminifera, age model adjustments, new and complementary reconstructions, we interrogate the evolving relationship between Earth's climate and CO_2, to identify tipping elements of the climate-CO_2 system and discuss potential mechanisms underlying such transitions.

Combining modern surface-to-seafloor eDNA datasets to unlock the potential of sedimentary ancient DNA.

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Recent ocean explorations using environmental genomics tools have revolutionized our understanding of plankton biodiversity at global scale and along the water column. These plankton genomic resources provide a fantastic opportunity to separate the plankton DNA signatures that have settled on deep seafloor sediments from indigenous benthic biodiversity. Combining modern surface-to-seafloor eDNA datasets not only allow us to specifically link plankton and benthic biodiversity to modern ocean ecosystems processes, but also unlock the potential of sedimentary ancient DNA (sedaDNA) for paleoceanography.
I will first give an overview of environmental genomics methods and the conceptual framework for using sedaDNA signal for paleo-reconstructions. Then, I will show how modern surface-to-seafloor eDNA datasets opens new research avenues in (paleo)ceanography. I will present ongoing work that aims at delivering sedaDNA-based reconstructions of Late Quaternary sea ice conditions in polar ecosystems and of the biological carbon pump in the North Atlantic. Finally, I will discuss technical challenges in sedaDNA data analysis and highlight potential solutions to mitigate those.

Constraints on volcanic and thermogenic carbon emissions during the Paleocene-Eocene Thermal Maximum

J. Frieling[1], M.T. Jones[2], I.M. Fendley[1,3], T.A. Mather[1], W. Xu[4] & X396 scientists

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Processes associated with the North Atlantic Igneous Province (NAIP) and surface carbon cycle feedbacks interacted to shape the Paleocene-Eocene Thermal Maximum (PETM, 56 million years ago). An enigmatic 100-kyr plateau or 'body phase' distinguishes the PETM carbon isotope excursion (CIE) from other Paleogene hyperthermal events and could signal long-term net-positive carbon cycle feedbacks, such as shale weathering or deep hydrates, unique to the most severe carbon cycle perturbations. To resolve whether such feedbacks are required to explain a long-lasting carbon-cycle perturbation, we generate a sedimentary mercury-based estimate of concurrent volcanic contributions, from both extrusive and intrusive igneous activity in sedimentary basins along the Northeast Atlantic margins. Samples obtained during International Ocean Discovery Program Expedition 396 from within a hydrothermal vent complex were analyzed for sedimentary mercury. Spatial patterns in Hg and Os isotope data during the PETM CIE show elevated volcanic fluxes and intense hydrothermal activity after sill intrusions. Using our Hg data and Hg:C ratios of modern systems, we estimate >4,000 petagrams of ^{13}C-depleted carbon (< -25‰) may have been released from combined NAIP-sources during the CIE body. This may have offset the observed enhanced organic carbon burial and other negative carbon cycle feedbacks, and reduces the need for major long-term positive feedbacks.

The ocean's biological carbon pump in a warming world: Insight from the past using marine barite

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As our oceans continue to warm in response to increased global temperatures, questions about the impact on nutrient cycling, primary productivity, and marine ecosystems remain. Looking to records of past change in deep sea sediment is critical to understand how the Earth system responded during prior warm intervals. Proxy records reconstructing the marine biological carbon pump in different regions in the ocean will be explored from three periods of interest including the Miocene Climate Optimum, Early Eocene, and Late Cretaceous. An emphasis will be on understanding biogenic barium proxy records. Pacing and potential drivers of change during these warm intervals differ, but all highlight the dynamic nature of the response of the ocean-atmospheric system in different regions and the importance of multi-proxy records. Special attention to assumptions and limitations of proxy records is necessary when comparing potentially conflicting records, which can ultimately provide invaluable insight into potential changes in carbon export at different depths in the ocean and nutrient cycling and their impact on marine ecosystems when thoughtfully combined.

The geologic history of marine dissolved organic carbon from iron oxides

Nir Galili[1], Stefano M. Bernasconi[1], Alon Nissan[2], Uria Alcolombri[2,3], Giorgia Aquila[1], Marcella Di Bella[4], Thomas M. Blattmann[1], Negar Haghipour[1,5], Francesco Italiano[6], Madalina Jaggi[1], Ifat Kaplan-Ashiri[7], Maxwell A. Lechte[8], Susannah M. Porter[9], Maxim Rudmin[10], Robert G.M. Spencer[11], Stephan Wohlwend[1], **Jordon D. Hemingway**[1]

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Dissolved organic carbon (DOC) is the largest reduced carbon reservoir in modern oceans. Its dynamics regulate marine communities and atmospheric CO_2 levels, whereas ^{13}C compositions track autotrophic metabolism. However, the geologic history of marine DOC remains entirely unconstrained, hindering our ability to mechanistically reconstruct coupled ecological and biogeochemical evolution. To address this, we developed the first direct proxy for past DOC signatures using co-precipitated organic carbon in iron ooids, and we applied this to 26 marine iron ooid-containing formations deposited over the past 1650 million years. Predicted DOC concentrations were near modern levels in the Paleoproterozoic then decreased by 90-99% in the Neoproterozoic before sharply rising in the Cambrian. We interpret these dynamics to reflect three distinct states: (i) small, single-celled organisms combined with severely hypoxic deep oceans; (ii) larger, more complex organisms and little change in oxygenation; (iii) continued organism growth and a transition to fully oxygenated oceans. Furthermore, modern DOC is significantly ^{13}C-enriched relative to the Proterozoic, likely due to changing autotrophic fractionation driven by biological innovation; together with isotopically invariant carbon inputs to Earth's surface, this implies increasing relative organic carbon burial through time. Our results reveal new connections between the carbon cycle, ocean oxygenation, and the evolution of complex life.

What were the drivers of the Paleocene carbon isotope maximum?

Michael J. Henehan[1,2,3], James S. K. Barnet[4], Boriana Kalderon-Asael[2], Shihan Li[5], Shuang Zhang[5], Volkan Özen[6], James W. B. Rae[4], Noah J. Planavsky[2], Ross Whiteford[4], James D. Witts[7], Thomas Westerhold[8], Ellen Thomas[2,9], Kate Littler[10], Friedhelm von Blanckenburg[3,11], and Pincelli M. Hull[2].

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The Paleocene epoch (66.02 – 55.98 Ma) is a critical interval spanning the post-extinction reassembly of marine ecosystems up to the dawn of the last hothouse period. It also saw one of the largest positive carbon isotope excursions of the Phanerozoic – the mechanisms for which remain uncertain – and a major step change in the Li isotope composition (δ^7Li) of seawater, commonly interpreted as a shift towards highly-weathered, peneplained continents. Despite this, the Paleocene has received little scientific attention relative to the charismatic events that bookend it. In particular, estimates of atmospheric CO_2 concentration over this interval are scant, meaning that the Paleocene often appears as anomalous in terms of global climate sensitivity. Here we present boron isotope-based records of Paleocene ocean pH and atmospheric CO_2, complemented by records of benthic and planktic foraminiferal δ^7Li that inform as to changes in global silicate weathering. We observe a steady decline in atmospheric CO_2 levels from the K-Pg towards the middle Paleocene, before CO_2 rises once more into the Eocene greenhouse period. We find no evidence for a state change in the weatherability of continents in the early Cenozoic, with continental weatherability broadly static over the Paleocene interval. Previous reconstructions of the δ^7Li of seawater are likely driven by variable foraminiferal ‘vital effects’ over the Cretaceous-Palaeogene mass extinction. Coupling of these constraints on weatherability and carbon cycling with iLOSCAR inverse carbon cycle modelling, points to large fluxes of organic carbon burial. This organic carbon was then likely oxidised and returned to the ocean-atmosphere system to sustain the early Eocene hothouse climate.

Decoding signals of biotic change in ancient records: The problem of rate scaling

Pincelli M. Hull[1] and the BioDeepTime Project Members

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The planet is ever changing and so too are the living communities that inhabit it. As a result, the fossil record records paleo-environmental dynamics and paleo-community across events spanning a range of severity – from background dynamics to responses to hyperthermals. In such records is the promise that we might begin to understand the dynamics and limits of biota during intervals of rapid global change. How much change is too much? How fast does global warming need to be in order in result in (mass) extinction? In this talk, I will address a major problem complicating the application of ancient records, and their lessons, to the modern biodiversity crises. The BioDeepTime project was formed several years ago to examine the dynamics and scaling of biodiversity dynamics in modern and ancient records, and has begun to map out issues of rate scaling and dynamics across realms, clades, and times. These early results from BioDeepTime provided bracketing context for reconsidering inferences across ancient hyperthermals.

Silicate weathering vs. organic carbon burial: Who wins?

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Negative feedback between climate and atmospheric CO_2, as mediated via weathering of silicate minerals, is thought to provide the dominant regulation of Earth's climate on geological timescales. In contrast, we show here that faster and more responsive feedbacks involving organic matter are not only critical to Earth system recovery from climate perturbation but can also create unexpected instability in the system. Specifically, using an Earth system model, we show how sedimentary organic carbon burial, amplified by climate-sensitive phosphorus feedbacks, can dominate over silicate weathering, paradoxically creating a cooler climate state in response to massive CO_2 release. This carbon-climate instability is most strongly expressed in the model at intermediate ocean redox states, which may help understand the timing of ice ages through Earth's history.

Pushing the proxies: Preservation, precision, & processes

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Future sea level change is one of the most serious, and yet poorly constrained, impacts of anthropogenic climate change. One of the issues is the lack of observational data of very slow, glacial processes, which makes them difficult to parameterise accurately in ice sheet models. Some attempts have therefore been made to “tune” ice sheet models using palaeoclimate records, and to use these tuned models to project future sea level rise. However, these projections are somewhat controversial, largely because of the uncertainties associated with the past sea level reconstructions. One way to reconstruct past changes in ice volume is through paired δ^{18}O-Mg/Ca paleothermometry, but the uncertainties in this approach have been estimated to be equivalent to half the mass of the modern Antarctic Ice Sheet, severely limiting the usefulness of this technique. Here I present our recent work improving the Mg/Ca palaeothermometer, which has reduced these uncertainties several fold. I also present some intriguing geochemical data and modelling results from the Oligocene-Miocene Transition (~23 million years ago), which casts some doubt on the traditional way we view the evolution of Earth’s Cryosphere as a simple progression from greenhouse to unipolar icehouse, to bipolar icehouse conditions.

Changes in climate sensitivity and polar amplification over the last 500 million years

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During the Phanerozoic (the last ~0.5 billion years), the Earth has experienced massive changes in climate, spanning the extensive glaciations of the Permo-Carboniferous (~300 million years ago), to the mid-Cretaceous super-greenhouse (~100 million years ago). Recently, several studies have used geological data to reconstruct global mean temperatures through this period, as a way of characterising the zeroth-order response of the Earth system to its primary forcings.
Here we use two new ensembles of model simulations covering the entire Phanerozoic, consisting of 2× >100 simulations at a 5 million year resolution, to explore the key metrics of climate sensitivity and polar amplification using the HadCM3 climate model. The model version we use has undergone a substantial development process and can simulate the climate of the Eocene, where extensive observations exist, at least as well as much more recent (CMIP5) models, but at a fraction of the computational cost.
The two ensembles explore uncertainty in the CO_2 forcing during the Phanerozoic, being forced by (a) a published CO_2 curve based on proxy reconstructions, and (b) a derived CO_2 curve that results in global mean temperatures in agreement with temperature reconstructions. Comparison of the ensembles indicates that the climate sensitivity is both temperature and paleogeography dependent, increasing with increasing temperatures, and varying as a function of the supercontinent configuration. We also explore polar amplification, and again find that this is dependent on background climate and paleogeography. We apply energy balance methods to explore the reasons for the varying polar amplification, and also find a key role for the ocean circulation state.

Combining terrestrial and marine evidence for state and timescale-dependency of surface climate variability with model constraints

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The power spectrum of surface temperature variability arises from the interactions between the climate system and external forcing. Comparing spectra from observations to that from model simulations with atmosphere-ocean-dynamic vegetation general circulation models (AOGCMs) shows that models simulate appropriate global mean surface temperature (GMST) variability from 1 to 200 years, but fail at the local scale at all timescales beyond the interannual. This uncertainty on regional climate variability hampers projections for short-lived climate extremes. Previously, this lack of variability has been attributed to the reliance on equilibrium simulations, lack of process and component representation and spatial resolution.
Here, we combine a comprehensive set of palaeoclimate reconstructions to establish the first composite spectrum of GMST for the last 2 Million years. The spectrum is largely state-independent, and shows power-law scaling, with a scale-break at millennial scale. Only simulations from AOGCMs with interactive ice sheets and transient volcanic forcing can match reconstructed regional variability in the mid and high latitudes. This points to limitations in state-of-the-art CMIP5/6 simulations and projections, which miss these feedbacks and natural forcing. Moreover, persistent disparities in tropical variability from models and reconstructions highlight gaps in the understanding of tropical climate dynamics. Refining climate models, experiments, and enhancing our comprehension of how the key components of the climate system interact across timescales is required to constrain future temperature variability and appropriate climate action.

The response of ocean oxygen-deficient zones to past climate changes: Evidence from fossil-bound nitrogen isotopes

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The availability of dissolved oxygen (O_2) is among the most fundamental constraints on life in the ocean, and it impacts the marine cycles of most biologically important elements. Moreover, the distribution of oxygen in the ocean interior reflects the carbon storage associated with the ocean's biological pump, which is, in turn, sensitive to the ocean's circulation and biological productivity. Thus, the response of ocean oxygen to climate change – past, ongoing, and future – is of great consequence. Based on oxygen measurements over decades, it has been argued that that the ocean's oxygen-deficient zones (ODZs) have been expanding due to global warming. Numerical ocean models, however, provide a complex picture of the ODZs in the global warming future. Studies of past warmer-than-modern periods can provide unique insight. The "denitrification" (reduction of nitrate to N_2) that occurs in the ocean's ODZs is reflected in the nitrogen isotopic composition of oceanic nitrate and the organic matter produced from it. I will describe nitrogen isotopic measurements of the organic matter bound within biomineral fossils (of foraminifera, otoliths, and corals) over a range of time scales that, together, indicate smaller ocean ODZs under warmer climate. I will then consider possible mechanisms, the implications for the climate dependencies of the ocean's oxygen, nitrogen, and carbon cycles, and the significance of the findings for anthropogenic global warming.

Revisiting Cenozoic deep ocean temperatures using clumped isotope thermometry

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To understand how the Earth system will operate under higher-than-present-day atmospheric carbon dioxide concentrations we must look to the geological record. On multi-millennial and longer timescales, deep-sea temperatures are thought to provide good indications of global climate. Yet, reconstructing reliable deep-sea temperatures throughout the Cenozoic is challenging. Our current understanding relies heavily on proxy records such as benthic foraminiferal stable oxygen isotopes, which reflect not only temperature, but are also affected by changes in the composition of seawater. Here we present records of deep-sea temperature change using clumped isotope thermometry, which permits explicit temperature reconstructions independent of seawater chemistry. We focus on pivot points in Cenozoic climate history, such as the abrupt onset of large-scale Antarctic glaciation approximately 34 million years ago, where the effects of non-thermal influences on more classical palaeothermometers are most acute. Many of our clumped isotope-derived temperature estimates suggest that deep-sea temperatures may have been warmer, and more spatially and temporally variable, than previously suggested. Clumped isotope thermometry thereby provides new opportunities to gain better insights into the evolution of ocean temperature and ocean circulation through time.

Estimating long-term mass accumulation rates in marine sediments: A new approach considering syndepositional redistribution in areas of strong bottom current dynamics

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Understanding oceanic particle fluxes from sediment records is vital for paleoceanographic research, guiding assessments of export production and terrigenous material supply rates. Traditionally, stratigraphy-based mass accumulation rates (BMARs), which are calculated by multiplying the sediment dry bulk density by the linear sedimentation rate between dated sediment horizons, estimate material fluxes to the seafloor. However, BMARs and the resulting paleoceanographic interpretations may need to consider the lateral redistribution of sediments to avoid substantial errors. Particularly in the Subantarctic Southern Ocean, lateral redistribution is common due to the strong bottom water circulation of the Antarctic Circumpolar Current, which impacts paleoceanographic interpretations. As a case study, we evaluate export production indicators over the past 1.4 million years at the Pacific entrance of the Drake Passage, correcting BMARs for sediment advection, we identify fluctuations in export production coinciding with major climatic events (The Mid-Pleistocene Transition and Mid-Brunhes Event). Additionally, the productivity response in the area was enhanced (weakened) during globally strong (faint) glacials or interglacials. Our study highlights the importance of considering lateral sediment movement for accurate paleoceanographic reconstructions and opens avenues for testing this approach in other oceanographic settings.

Gaining a dynamical understanding of hydroclimatic extremes over the past millennium from proxies and climate models

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Proxy-model synthesis provides a useful tool for understanding variability and change in hydroclimatic extremes over the last millennium. An overview is provided on how to combine a diverse set of proxies with annual to (multi-)decadal resolution from the terrestrial and marine realms (e.g., speleothems, tree-rings, corals, bivalves, lacustrine and marine sediments) with state-of-the-art climate model simulations to investigate the relative contributions of internal and external climate drivers to (sub)tropical hydroclimate variations across a range of timescales. The focus is on the Austral-Asian monsoon systems, key climate modes in the Indian and Pacific Oceans such as the El Niño-Southern Oscillation, Indian Ocean Dipole, Interdecadal Pacific Oscillation, as well as their interactions as mediated through variations in the zonal and meridional overturning circulations (i.e., Walker and Hadley circulation) and their hydroclimatic impacts in surrounding regions as mediated by atmospheric teleconnections.

Climate-carbon cycle interactions from the Pliocene to the deep future

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Atmospheric CO2 influences climate mainly through its greenhouse effect, and climate in turn affects many carbon cycle processes, primarily through their temperature dependence. Different carbon cycle processes in the Earth system operate on very different time scales ranging from seasonal/annual to >100,000 years, resulting in climate-carbon cycle interactions across a wide range of time scales.
Here we use the CLIMBER family of fast Earth system models to explore and better understand the climate carbon-cycle interactions from the Pliocene to 200,000 years into the future. We show that small imbalances in the carbon cycle result in long-term trends of atmospheric CO2 that influence climate leading to the Pliocene-Pleistocene transition and to glacial inception in the future. During glacial-interglacial cycles of the Pleistocene carbon cycle dynamics amplified the climate and ice sheet response to orbital forcing. We finally show that atmospheric CO2 concentration exerts a strong control on the appearance of millennial-scale climate variability, both in the past and in the future, and propose an explanation for the different CO2 response to Dansgaard-Oeschger and Heinrich events.

Macroevolutionary and biogeographic response of marine plankton to Cenozoic climate evolution

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The origin and maintenance of the latitudinal biodiversity gradient (LBG) remains relatively obscure, especially with respect to past and future climates. LBG studies typically adopt a species-based-perspective, rather than a functional or trait-based one, especially in paleontological studies. Unlike species, which are evolutionarily ephemeral, functional groups can be consistent across an entire clade's history, providing broader perspectives on biotic and abiotic processes.
Using Triton, a global dataset of Cenozoic macroperforate planktonic foraminiferal occurrences, we contextualize changes in functional diversity, paleolatitudinal specialization, and community equitability across the Cenozoic using network analyses. We identify: 1. specialized morphological communities in the aftermath of the Cretaceous-Paleogene extinction, 2. global ecological specialization of communities during the Early Eocene Climatic Optimum, 3. an increase in specialized morphological communities which precede losses in diversity by millions of years in response to Antarctic glaciation initiation, 4. global morphological specialization and richness change ~19 Ma, coeval with pelagic shark extinctions and changes in ocean nutrient dynamics, and 5. a significant delay between niche exploitation and diversification as bipolar ice sheet expansion triggered global paleoceanographic change.
Overarchingly, we find that the functional responses of communities to large-scale Cenozoic climate events are separated from richness loss/gain, revealing novel structural changes important for understanding how marine ecosystems respond to global change in past, present and future oceans.

List of Abstracts: Posters

Ocean Floor Symposium 2024
“Scenarios for Warmer Worlds: Lessons from the Past”

May 13 – May 16, 2024
at
MARUM – Center for Marine Environmental Sciences,
University of Bremen

Natural carbon sequestration process into shallow sill intrusions – Geochemistry and numerical modelling, land-based and IODP drilling investigations

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Permanent carbonate mineralisation in basalt is a promising solution for Carbon Capture and Storage of anthropogenic greenhouse gases without the risk of leakage. While this process is known to occur at relatively low temperatures below 100°C, new research on Large Igneous Provinces (LIPs) and young rift basins suggests that much of the thermogenic gases mobilised during contact metamorphism can remain trapped and mineralised in the sills that mobilised them. This discovery is the result of two distinct drilling investigations on land (KARIN) and at sea (IODP Exp 385). It shows that basalts may not only trigger the sudden release of thermogenic gas, but also represent an important carbon sink. The two examples of carbonate trapping in sills presented here are from the Karoo and Guaymas basins. Results indicate that a large fraction of epimagmatic fluids charged with thermogenic gas systematically penetrated inside the sills during cooling. Our numerical solutions suggest that in both cases the higher permeability of the sill acquired during cooling and crystallisation compared to that of its host, ultimately dictates the fate of the thermogenic gas that accumulated in the igneous bodies

The biological carbon pump at the PETM: New stable-isotope records from ODP 1209/1263

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The Paleocene-Eocene Thermal Maximum (PETM, ~56 Ma) is an important test case for the effects of rapid warming on marine ecosystems and carbon cycling. Existing proxy records broadly indicate stable surface productivity during the PETM but reduced organic carbon export to the seafloor, suggesting the possibility of a systematic collapse in the efficiency of the biological carbon pump. If true, theory suggests that such a collapse may be visible as a reduction in the surface-to-twilight-zone gradient in stable carbon isotopes of dissolved inorganic carbon ($\delta^{13}C_{DIC}$). To test this, we present new high-resolution, single- and multi-shell, multi-species $\delta^{13}C$ and $\delta^{18}O$ data from ODP 1209 (North Pacific) and ODP 1263 (South Atlantic) across the PETM boundary. At both sites, the core PETM is associated with a marked reduction in the preexisting $\delta^{13}C$ offset between typically mixed-layer-dwelling *Morozovella* + *Acarinina* spp. and typically deeper-dwelling *Subbotina* spp., as previously observed at (e.g.) ODP 690. For ODP 1209 in particular, this phenomenon cannot be explained by changes in photosymbiosis, depth habitat, or size-dependent mixing/filtering alone, suggesting the likelihood of a true homogenization of $\delta^{13}C_{DIC}$ values across the thermocline. Analysis of a global compilation of $\delta^{13}C$ and $\delta^{18}O$ data suggests that such a homogenization may be a geographically widespread feature of the PETM onset. Alternative interpretations are discussed.

Reconstructing the past functioning of the biological carbon pump: A sedimentary ancient DNA approach

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The biological carbon pump (BCP) is a major component of the oceanic carbon cycle, contributing to the downward transport of organic matter and the sequestration of carbon in the deeper layers of the ocean for hundreds to thousands of years. The BCP plays a pivotal role in regulating Earth's climate system, yet uncertainties persist regarding the potential impact of ongoing climate changes on its strength. Filling this gap is crucial as a weakened BCP represents positive feedback on atmospheric CO_2 levels and amplification of global warming.
Understanding the functioning of the BCP during past warm and cold climates can provide valuable insights into its past dynamics and potential future behaviour. The efficiency of the BCP is closely tied to plankton community composition, with differences in size and morphology shaping the quality, quantity and speed of sinking particulate organic carbon (POC) reaching the seafloor. Recently, sinking plankton DNA signatures within deep-sea sediments were found to explain variations of POC flux reaching the seafloor in the modern ocean. This opened the possibility of using the plankton fraction of sedimentary ancient DNA (*seda*DNA) to reconstruct past POC flux from the geological record. I will present how we plan to develop *seda*DNA as a proxy for POC flux as well as preliminary results obtained with DNA metabarcoding (targeting Eukaryotes with the ribosomal 18S-V9 region) that reveal shifts in plankton and benthic diversity in response to past climate variations.

Hydrologic variability in the southwest Indian Ocean from Mauritius corals since the late 19th century and connections to the Indo-Pacific

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In the Indian Ocean observational records of salinity are not well constrained prior to the early 2000's making any understanding of decadal to interdecadal changes difficult. We present a paired Sr/Ca and $\delta^{18}O$, bimonthly record of a shallow water coral from the southwest Indian Ocean (Mauritius, 20.34°S, 57.55°E), extending from 1882 to 1989. The coral Sr/Ca proxy tracks SST of the wider open ocean well, providing confidence to current coral temperature reconstructions. Our record highlights the strong increasing SST trend. Paired analysis allows for $\delta^{18}O_{sw}$ reconstruction, developing the first high-resolution hydroclimate record extending past the start of the 20th century. The coral $\delta^{18}O_{sw}$ record captures Mauritius rainy season precipitation, exhibiting a strong relationship to in-situ precipitation across the island. The relationship to Mauritius rainy season captures wider scale precipitation associated with the transition of the ITCZ. It is suggested the non-rainy season $\delta^{18}O_{sw}$ variability is controlled by oceanic processes as Mauritius lies along the South Equatorial Current, an important connection between the Pacific and Indian Ocean. Using a network of coral reconstructions from the southwest Indian Ocean, and the new Mauritius coral record, we reveal variability across the region under past, present, and future climate change. This study uses legacy data as part of the DFG-Priority Programme "Tropical Climate Variability & Coral Reefs" (SPP 299).

Sea surface temperatures across the low-latitude Indo-Pacific Ocean during the Holocene, last interglacial and marine isotope stage 11

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The Indo-Pacific Warm Pool (IPWP) holds the largest warm water body on Earth. Sea surface temperatures (SST) above 28°C promote deep atmospheric convection with far-reaching climate impacts. Spatiotemporal changes in SST influence the location and strength of atmospheric convection and thus the atmospheric circulation. With respect to the projected global warming, a thorough reconstruction of SST and its spatiotemporal variability during previous interglacial periods is therefore an enduring issue. Hitherto, global compilations of interglacial SST anomalies and data-model comparisons have mostly focused on the Holocene and Last Interglacial (LIG) period and reveal a striking mismatch between proxy-derived and modelled SST anomalies in low latitudes. However, the data coverage across the Indo-Pacific is poor with little to no data from the IPWP. We compare a proxy network of SST anomalies from the low-latitude Indo-Pacific during the Holocene, LIG and MIS 11 to the output of CESM 1.2 simulations. We find large discrepancies in magnitude and pattern of SST change. For instance, proxy data indicate highest SSTs during the LIG, slightly warmer than the preindustrial period, while CESM shows lowest SSTs during the LIG. We use individual forcing experiments to disentangle the roles of orbital forcing, greenhouse gas concentration and vegetation cover in shaping SST patterns and particularly find that an expanded Northern Hemisphere vegetation cover mitigates data-model discrepancies.

A late Paleocene - early Eocene record of calcareous nannofossil community composition from the high-latitude South Pacific Ocean

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The high carbon dioxide (CO_2), hothouse world of the late Paleocene – early Eocene (~48 to 56 million years ago) is generally considered to provide one of the best geological analogs for modern environmental change. This interval is also characterized by a series of transient warming (hyperthermals) the largest of which – the Paleocene-Eocene Thermal Maximum (PETM) – led to the extinction of ~30 to 50 % of deep-sea (benthic) foraminifera. Although planktonic organisms (i.e., those that lived at or close to the sea surface) were not as significantly affected by this warming event, they still experienced major changes in community composition. This is particularly true of calcareous nannoplankton (golden-brown algae that lie at the base of the marine food web and are a critical component of marine biogeochemical cycling) which produce microscopic calcium carbonate plates that readily fossilize and are preserved in abundance within deep-sea sediments.
Although a wealth of research has been conducted on nannofossil community composition during the late Paleocene to early Eocene interval, most work only focuses on the PETM and not the hyperthermals that preceded or succeeded it. However, examining these events together may reveal important information that is currently uncertain such as whether marine plankton experience a threshold or scaled response to warming. Furthermore, most of our high-resolution records were generated using sediment cores from low to mid-latitude sites, which are not necessarily representative of changes in community composition at relatively understudied high-latitude sites. In an attempt to help fill these 'knowledge gaps', we present here a longer-term record of paleoecological change - which spans several of the early Eocene hyperthermals - from the high-latitude South Pacific Ocean (International Ocean Discovery Program Site U1553). Our results indicate that changes in calcareous nannofossil community composition at high latitude sites are distinct from those at the lower latitudes during the PETM, with significant ecological jostling occurring both before the onset of the event and following its termination.

Plankton biogeography reveals strong temperature gradients in the ice age North Atlantic Ocean

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The cold Last Glacial Maximum, occurring around 20,000 years ago, provides a useful test case for evaluating whether climate models can simulate past climate states distinct from the present. However, because of the indirect and uncertain nature of proxy records of past environmental variables like sea surface temperature, such evaluation remains ambiguous. Instead, we here evaluate simulations of Last Glacial Maximum climate by relying only on the fundamental macroecological principle of decreasing community similarity with increasing thermal distance. Our analysis of planktonic foraminifera species assemblages from 647 sites covering the Last Glacial Maximum reveals that the similarity decay pattern that we obtain when the simulated Last Glacial Maximum seawater temperatures are confronted with species assemblages from that time differs from the modern. This inconsistency between the modern temperature dependence of plankton species turnover and the simulations arises because the simulations show globally rather uniform cooling for the Last Glacial Maximum, whereas the species assemblages indicate stronger cooling in the subpolar North Atlantic. We show that the implied steeper thermal gradient in the North Atlantic is more consistent with climate model simulations with a reduced Atlantic Meridional Overturning Circulation. Our approach demonstrates that macroecology can be used to robustly diagnose simulations of past climate and highlights the challenge of correctly resolving the spatial imprint of past global change in climate models.

Impact of anthropogenic CO_2 on the next glacial inception

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Anthropogenic CO2 emissions will have a very long lifetime in the atmosphere, persisting for hundreds of thousands of years. This will have unexpected consequences on the timing of the next glacial cycle, which is not only dependent on changes in solar insolation, but also much of this energy is retained. Although simulated atmospheric CO2 can be used to diagnose the potential timing based on a critical CO2–insolation relation, most previous studies on deep-future CO2 concentrations assumed that the climate would relax back to pre-industrial conditions following the perturbation. In addition to this, all studies fail to consider the interaction of CO2 on ice sheets. Here, we use the fast Earth system model CLIMBER-X to provide a set of long-term transient coupled climate-carbon cycle simulations under different emission scenarios for the next 200 kyr. This is used to diagnose the potential timing of the next glacial inception. We show that assumptions made on the pre-industrial state of the carbon cycle have profound implications on the timing of the next glacial inception, and explore how it depends on the magnitude of cumulative carbon emissions. Our simulations confirm that the natural length of the current interglacial is much larger than previous ones, and that glacial inception under natural conditions would occur around 50 kyr AP. Furthermore, we find that present-day cumulative carbon emissions are not sufficient to delay the next glacial inception, contrary to previous studies. In a second step, we run additional simulations including a coupled ice-sheet model, where we confirm the diagnosis and show ice sheet volume and extent at the next glaciation.

Carbon Dynamics and Sea Surface Temperature in the Late Eocene to Oligocene Transition in the South Pacific: Insights from Site U1553, IODP Expedition 378

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The late Eocene and the Oligocene represent a captivating era marked by diverse climate conditions ranging from "warmhouse" to "coldhouse" periods. This epoch also witnessed the presence of dynamic ice sheets on Antarctica and potentially fluctuating atmospheric CO_2 levels. Despite its significance, the correlation between CO_2 levels and the growth-and-retreat patterns of ice sheets, crucial for determining CO_2 thresholds for ice sheet stability across different climate phases, remains largely elusive. Moreover, CO_2 reconstructions for this period are scarce. Utilizing the high latitude site U1553 in the South Pacific, we conduct high resolution reconstructions of CO_2 using planktonic and benthic foraminifera. Our analysis encompasses multiple species of foraminifera, examining stable isotopes, trace elements, and boron isotopes. Through this comprehensive approach, we delve into foraminiferal "vital-effects" and aspects of the marine carbonate system. This forms a solid foundation for generating continuous, long-term records of CO_2 levels and seawater temperatures throughout the late Eocene and the Oligocene. Our findings, presented here, shed light on our evolving understanding between temperature variations, the carbon cycle, and salinity dynamics during Eocene Oligocene Transition.

References:

[1] Westerhold, T. et al. Science 369, 1383 (2020)

Increase in strength and orbital variability of the South Pacific Antarctic Circumpolar Current across the Mid-Pleistocene Transition

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The Antarctic Circumpolar Current (ACC) impacts global ocean circulation, climate, and Antarctic ice sheet stability. Yet, its role in driving the lengthening and intensification of glacial cycles is insufficiently studied. Here, we present a 1.5 Ma-record of changes in ACC strength and sedimentary opal contents at IODP Sites U1540 and U1541 drilled in the Subantarctic Zone (SAZ) of the Pacific Southern Ocean. Our records indicate that glacial and interglacial ACC strength gradually increased during the early part of the MPT. This interval culminates in a pronounced ACC maximum during MIS 31 at ~1 Ma reaching ~160 % of the mean Holocene values. The increase in subantarctic ACC strength is paralleled by the emergence of stronger orbital-scale fluctuations in opal contents after MIS 31, suggesting a link between the onset of consistently higher amplitude glacial-interglacial fluctuations of ACC changes and latitudinal shifts of the 'opal belt' in the Southern Ocean. We argue that the early change in ACC dynamics at the beginning of the MPT might be linked with sea surface temperature cooling in the eastern subtropical and tropical Pacific. This may result from enhanced advection of subantarctic water masses northward along the Humboldt Current system as a response to the intensification of the ACC. Our findings emphasize a contribution of Southern Ocean processes to the climate events causing intensification of glacial-interglacial climate variability during the MPT.

Quantifying key drivers of marine pyrite content and isotopic composition

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Microbial sulfate reduction coupled to pyrite burial in marine sediments plays a crucial role in Earth's carbon and oxygen budgets. By reducing sulfate, this process increases atmospheric O_2 and lowers CO_2. Traditionally, pyrite sulfur-isotope compositions have been interpreted to reflect global sulfur cycling or microbial behavior. However, recent studies point to greater importance of local factors, but quantifying these remains challenging. To address this issue, here we developed a non-dimensional model that accurately predicts modern observations for a suite of global marine core data. We estimate global pyrite burial to be ~4.2×10^{14} g yr^{-1}, with buried pyrite containing an average $\delta^{34}S$ value near -3 ‰ VCDT. This burial flux is substantially higher than recent estimates of terrestrial pyrite weathering, suggesting the modern sulfur cycle results in net pyrite burial and thus atmospheric O_2 accumulation. We find that pyrite formation rate is driven by local iron input, whereas $\delta^{34}S$ is influenced by organic carbon reactivity-to-sedimentation rate (quantified as Da*, a modified Damköhler number) and organic carbon-to-sulfate ratio (termed Γ_0). Changes in the sulfur cycle since the Paleozoic suggest shifts in organic matter reactivity and sulfate concentrations, requiring increased Da* and decreased Γ_0 for the modern sulfur cycle.

SPiraling Intelligent Robotic Underwater monitoring pLAtform (SPIRULA) – towards repeated, high density and low-cost seafloor monitoring

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A robust seafloor monitoring system, that enables repeated surveys of an area of interest over extended periods of time (weeks or even months) is valuable in various aquatics applications, such as medium and long-term observations of environmental changes and their effects on the local flora and fauna. Other applications might include monitoring gas seeps, assessing general ecosystem-related changes, or monitoring processes related to ocean chemistry.

Existing technologies have been used in all of these application areas to some extent, but rarely on a longer-term operational basis. The aim of SPIRULA is to offer an affordable, robust, and compact solution for such tasks. A key concept is the use of a hybrid monitoring platform that comprises a static lander and an autonomous mobile underwater vehicle (measuring 1 m x 0.4 m x 0.6 m and weighing 37 kg) directly tethered to the lander. This hybrid structure enables the utilization of the superior temporal monitoring capacity of static landers along with the enhanced spatial monitoring of mobile platforms. Although directly tethering the vehicle to the lander limits the spatial coverage to approximately 1000 m^2 for 20 m long tether, it significantly increases the platform's robustness and reduces the vehicle's size and complexity. The tethered connection forces the vehicle onto a spiralling path around the lander, enabling a dense and efficient georeferenced coverage of a circular area.

Coccolith clumped isotopes reveal temperatures of modern, Miocene and Cenozoic euphotic oceans

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The application of clumped isotopes (Δ_{47}) to calcite from coccolithophores holds promise for refining absolute temperature reconstructions of euphotic oceans.
Coccolith Δ_{47} from tropical Holocene sediments suggest that coccolithophores inhabit deeper than surface waters, challenging previous assumptions used by widely-used proxies calibrated to Sea Surface Temperatures (SSTs). At higher latitudes, Holocene coccolith Δ_{47} temperatures agree better with SSTs, likely indicating mixed layer temperatures.
Modest, rather than extreme polar amplification is suggested by Δ_{47} from pure North Atlantic coccoliths for the last 16 Ma. An average 10°C colder North Atlantic compared to alkenone temperatures not only agrees better with modern SSTs, but also with climate models.
Low-resolution low and high latitude coccolith Δ_{47} trends across the Cenozoic agree with the general climate pattern expected from foraminiferal $\delta^{18}O$. However, the Eastern Equatorial Pacific appear unexpectedly cold, possibly due to early recrystallization or upwelling dynamics. coccolith Δ_{47} from the South Tasman Rise suggest a similar magnitude of polar amplification as the one observed for the North Atlantic around the MCO. Preliminary SEM and trace elements do not show evidence of recrystalization in our samples, but a full analyses may indicate the reason for the cold absolute values in our tropical record.

Dominant control of temperature on (sub-)tropical soil-carbon turnover

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Carbon storage in soils is important in modulating atmospheric carbon dioxide concentrations (CO_{2atm}). However, uncertainty exists regarding the sensitivity of the soil carbon pool to temperature and hydrologic forcing. While temperature is thought to exert the dominant control on soil carbon turnover times in high and mid latitudes, hydroclimate has been inferred to have the dominant effect in low latitudes. This study uses radiocarbon dating of plant-derived lipids in conjunction with temperature and rainfall estimates from an eastern Mediterranean sediment core receiving terrigenous material from the Nile-River catchment to investigate turnover times of soil carbon in subtropical and tropical areas during the last deglaciation. We find that deglacial warming drastically accelerated the soil-carbon cycle by enhancing respiration rates and was more important for turnover times than rainfall variability. Our data suggest that the temperature sensitivity of soil carbon turnover was relatively high during the colder glacial and deglaciation. Increased efflux of CO_2 from soil to the atmosphere due to amplified respiration rates constitutes a positive feedback to global warming. However, simulated glacial-to-interglacial changes in a dynamical global vegetation model underestimate our data-based reconstructions. This suggests that the temperature-controlled soil carbon turnover time in models is still biased preventing a precise assessment of this climate feedback.

Apparent diachroneity of calcareous nannofossil datums during the early Eocene

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The late Paleocene to early Eocene period witnessed significant carbon perturbations leading to hyperthermal events, with the Paleocene-Eocene Thermal Maximum (PETM) being the most notable. These hyperthermals are identified in sediments by paired negative $\delta^{13}C$ and $\delta^{18}O$ excursions, in addition to decreased calcium carbonate and increased iron content caused by carbonate dissolution. However, current data are predominantly sourced from the equatorial- to subequatorial regions. Here we present a new high-latitude record, recovered during International Ocean Discovery Program (IODP) Expedition 378 off New Zealand, in the southwest Pacific. To construct an age model, we correlated our chemostratigraphic and biostratigraphic data to existing astronomically-tuned age models from Walvis Ridge and Demerara Rise. Our results indicate that the Site U1553 composite section spans ~7 million years of the latest Paleocene to early Eocene (50.5 to 57.5 Ma), and preserves many of the hyperthermals including a PETM interval. However, construction of the age model also revealed discrepancies between the chemostratigraphic and biostratigraphic tie points used for correlation. This is likely due to latitudinal diachroneity in the calcareous nannofossil biostratigraphic datums, which are primarily based on lower latitude assemblages. The study highlights the need to establish a revised calcareous nannofossil biozonation that is more appropriate for high-latitude age models.

A high-resolution palynological perspective on ecosystem overhaul during the earliest phases of the Paleocene-Eocene Thermal Maximum

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The Paleocene-Eocene boundary is marked by a 2-8‰ carbon isotope excursion (CIE) with a sharp (<5 kyr) onset that is followed by a ~200 kyr period of extreme global warming, the Paleocene-Eocene Thermal Maximum (PETM; 56 million years ago). The PETM is often referred to as our best analogue for future climate change. Although prominent changes in marine and terrestrial ecosystems have been recorded during the PETM, high resolution (sub-millennial-scale) records of the crucial onset phase remain extremely scarce.
Here, we present new palynological data from the Norwegian Margin covering the onset of the PETM CIE at a resolution of ca. 200 years, obtained from microlaminated sediments that provide precise control on accumulation rates. Our results show the collapse of a Cupressaceae-dominated forest, coeval with the initial δ13C decrease, followed by several stages of vegetation succession. During the CIE onset, marine dinoflagellate cyst assemblages become dominated by *Apectodinium* spp, indicative of rapid warming. This is rapidly replaced by an assemblage that signals reduced salinity conditions within ~500 years after the CIE onset, in the body of the PETM. Finally, the local-regional interaction between marine and terrestrial ecosystem changes as well as implications for global carbon cycle and climate change are discussed.

Constraining the influence of oceanographic and environmental conditions on the variability of Last Interglacial Mediterranean molecular proxy-based sea surface temperature reconstructions

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The Last Interglacial (~129,000-116,000 years ago) is the most recent warmer-than-present period in Earth's history. Sapropel S5 from core M51/3-SL104, deposited during this period, is varved for most of its extension and thus presents an excellent archive to study the high-resolution paleoclimate evolution of the Mediterranean region.
We recently applied mass spectrometry imaging (MSI) to long-chain alkenones from saproepl S5 in order to reconstruct sea surface temperature (SST) changes during this period in annual to subdecadal resolution. To provide a better understanding of the relation between SST and changes in environment and oceanographic conditions, we here present MSI data from the same archive, but targeting an alternative SST proxy based on glycerol dialkyl glycerol tetraethers (GDGTs).
GDGTs are produced by planktonic archaea and are recognized as important biomarkers for SST reconstruction. However, under the highly stratified nutrient-rich conditions prevailing during the Mediterranean sapropel S5 deposition, marine Thaumarchaeota may reside at the chemocline and record a signal that is not representative of SST. In this study, we will compare ultra-high resolution GDGT-based and alkenone-based SST records to obtain information about how ocean circulation influences SST reconstructions during sapropel S5 deposition. We will explore the variability and phase relationship between two different SST records in multidecadal to multicentennial time bands.

Application of the boron isotope palaeobarometer to investigate cryosphere-carbon cycle feedback

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Understanding the complexities of Earth's past climate transitions is crucial for deciphering the drivers and dynamics of contemporary and future climate change. In this study, we will embark on a multifaceted exploration focusing on the pivotal Eocene-Oligocene Transition (EOT). The first aspect of our investigation will refine boron isotope ($\delta^{11}B$) analysis in our CELTIC lab. Foraminiferal $\delta^{11}B$ is a key proxy for atmospheric CO_2 concentrations (pCO_2). We aim to optimize our methods to improve sample size requirements and analytical precision. Building upon these optimized analytical methods, our second objective is to produce high-resolution CO_2 records spanning the EOT, to shed light on the dynamics of atmospheric CO_2 concentrations during this critical period. The observed large rebound in pCO_2 following the expansion of ice sheets poses intriguing questions regarding the stability of the Antarctic Ice Sheet to CO_2 forcing, and also feedbacks within the global carbon cycle. In the third component, we aim to explore whether the EOT could serve as a palaeoclimate example of cascading tipping points. By examining specific interactions between critical Earth system components, such as the cryosphere and carbon cycle, we seek to elucidate the extent to which they may have triggered a series of tipping points, fundamentally altering Earth's climate state.

Foraminifera-bound organic matter nitrogen isotopic composition records marine environmental perturbations across the Cretaceous/Paleogene boundary

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The global environment was greatly perturbed at the Cretaceous/Paleogene (K/Pg) boundary, marked with ecological turnover, warming and ocean acidification. The ocean carbon cycle was also significant affected, recorded in the collapse of surface-to-deep gradient of carbon isotopes ($\delta^{13}C$). This global $\delta^{13}C$ change has been interpreted as a weakening of the biological export production in response to the mass extinction. To gain additional insights into the marine nutrient cycles, we measured the nitrogen isotopes of mixed-species planktonic foraminifera-bound organic matter (FB-$\delta^{15}N$) across the K/Pg boundary from Atlantic (DSDP Site 525A, ODP Sites 1049C and 1050C) and Pacific Ocean (ODP Site 1210). The FB-$\delta^{15}N$ elevated significantly across the K/Pg boundary on both Atlantic and Pacific basins. The Atlantic record indicated maintained elevated FB-$\delta^{15}N$ for about three million years, the timescale of which is aligned with inferred full ecosystem recovery from the carbon isotopes. Additionally, a decrease in FB-$\delta^{15}N$ occurred around 200 kyr prior to the K/Pg boundary, aligning with a decrease in foraminiferal $\delta^{18}O$. Similar to other Cenozoic FB-$\delta^{15}N$ records, we tentatively interpreted the FB-$\delta^{15}N$ change as an increased rate of water column denitrification. The significant FB-$\delta^{15}N$ increase across the K/Pg might be associated with expanding size of ocean suboxic zones, potentially driven by changes in the class size of sinking materials in the water column after the K/Pg.

Fish as an indicator of marine ecosystem structure, function, and evolution in deep time

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Fish are the most diverse group of vertebrates on the planet and are a significant protein resource for more than half of the world's population. Thus, understanding how fish and respond to changes in their environment, and under extreme hothouse conditions, is essential to mitigating anthropogenic impacts on the ocean. While fish are a relatively small part of the global ocean carbon cycle, their position at the top of the marine food web makes them particularly sensitive to changes that occur at the base and intermediate levels of the ecosystem, as the type and abundance of fish present depends on the environmental conditions and food web processes in the local area, with factors such as local productivity, temperature, and ocean currents all playing a role in determining the diversity and abundance of marine life. Therefore, fish can offer a window not only into how complex, multicellular life may respond to known environmental change, but fluctuations in fish abundance and diversity are reflective of overall ecosystem structure and functional shifts which may not be recorded in other records. Here I use records of ichthyoliths –isolated microfossil fish teeth and shark scales composed of biogenic phosphate (apatite) – from deep sea sediments, to explore fish and shark population and evolutionary dynamics during the Paleogene greenhouse, investigating whole ecosystem response before, during, and after past global change events including global warming and cooling events, as well as mass extinctions. Together these records demonstrate the importance of higher order consumers to the structure, function, and evolution of marine ecosystems.

Unravelling the long-term response of marine plankton biodiversity to climate change since the Last Glacial Maximum

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Current global warming is already affecting global marine biodiversity and is expected to have a stronger effect in the future. Here, we use the fossil record of planktonic foraminifera, coccolithophores, and dinoflagellate cysts to determine how their biodiversity responded to past climate change with a magnitude that is comparable to projected future warming. The compiled time series are located in the North Atlantic Ocean, cover a latitudinal range of 75°N to 6°S and span the past 24 kyr – the period from the Last Glacial Maximum (LGM) to the Holocene. All three examined groups exhibit analogous patterns of biodiversity change and overall assemblage change over time. In general, assemblages started to change with the onset of global warming around 17 ka ago and sustained a consistent rate of change throughout the Holocene, extending to at least 5 ka ago. The climatic shift from the LGM to the Holocene resulted in a prolonged period of change in both zoo- and phytoplankton assemblages. This change persisted well beyond the deglacial warming and is likely associated with new ecological interactions. It is conceivable that there was also a shift in the predominant drivers of plankton assemblage dynamics, transitioning from a dominance of abiotic factors during the last deglaciation to a greater influence of biotic factors with the onset of the Holocene. These findings indicate that future global warming may also have long-term consequences for marine plankton communities.

A shift in the mode of deep-sea silicon burial and its implications for Cenozoic cooling

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Deep-sea sedimentation rates increased and bottom-water temperatures declined in the later Cenozoic, which diagenetic modeling suggests would have resulted in a greater proportion of the biogenic silica reaching the seafloor being preserved. If the influx of silica to the global ocean was consistent through the Cenozoic, mass balance constraints necessitate that the proportion of silicon buried in other settings—namely, shallow marine environments or incorporated into clays (i.e. reverse weathering)—would have needed to have been greater earlier in the Cenozoic than today. Unlike the burial of weathering products in the form of SiO_2 and $CaCO_3$, which removes carbon from the coupled ocean-atmosphere system, reverse weathering releases carbonic acid back into the system and thus does not constitute a sink for carbon. Here, using a diagenetic model of silica dissolution and a carbon system model, we investigate the implications of a lower deep-sea silica burial efficiency on the silicon and carbon cycles. We further explore the potential climatic consequences of a secular shift in the mode of Si burial from biogenic silica to authigenic clays and consider it as a possible amplifier of Cenozoic cooling.

A new deep sea reference record for the Paleocene-Eocene Thermal Maximum: IODP Expedition 392 Site U1580 (Agulhas Plateau, Southwest Indian Ocean)

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The abrupt onset of the Paleocene-Eocene Thermal Maximum (PETM) 56 million years ago represents the one of the largest transient greenhouse gas-driven global warming event in the Cenozoic. Caused by a geologically rapid injection of exogenic carbon into the ocean and atmosphere system, the PETM is associated with large-scale ocean acidification. Related widespread dissolution of marine pelagic carbonate deposits complicates marine paleoclimatic reconstructions and the establishment of robust age models at many sites. Recently, a new deep-sea sediment record spanning the PETM was recovered from the southern Agulhas Plateau in the Southwest Indian Ocean during International Ocean Discovery Program Expedition 392. The uppermost Paleocene/lowermost Eocene interval at Site U1580 was drilled in two parallel holes at 2560 m water depth, and consists of 75–95% carbonate across the event, with a reduction to 75–65% at the PETM onset. X-ray fluorescence-derived core scanning elemental data at 5mm and 10mm resolution and an unprecedented high-resolution bulk carbonate stable carbon and oxygen isotope record define a new marine composite reference record for the PETM at this site. The record is comparable to Ocean Drilling Program Site 690 (2914 m water depth) in the Atlantic sector of the Southern Ocean, where the event was first described and is still a primary reference sequence for paleoclimate reconstructions. Highly resolved bulk carbonate stable carbon isotope record provides a new reference for global correlation of the PETM. Here we present this new record and discuss the implications for timing and duration of the event, and set the stage for multi-proxy paleoclimate reconstructions spanning the PETM at IODP Site U1580.

Paleogeography controls of dust emissions and their marine biogeochemical response over the Phanerozoic

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Desert dust is a vital component of the Earth's climate system. The climate system regulates dust emission processes, such as sediment availability and wind entrainment, in various ways. Dust modulates the Earth's radiation balance, and wind-carried dust deposition provides essential nutrient iron to land and marine ecosystems. While dust science is well-developed for the modern and the Quaternary (the last 2.6 Ma), little investigation has been done for the Earth's deep time.
Here, we present for the first-time continuous simulations of dust emissions, depositions, and resultant bioavailable iron throughout the Phanerozoic era (since 540 Ma ago). Results are derived from multiple schemes based on the paleoclimate fields output produced by the General Circulation Model HadCM3L. Our results show how dust emissions fluctuated over time with a stage-level resolution (approximately 5 Ma). We then diagnosed the controls of these fluctuations, and identified that paleogeography changes are the dominant control, whereas CO_2 plays a marginal role. Our ongoing work investigating how the deposited dust has impacted ocean production and oxygenation over multiple deep-geologic time slices, simulated by the cGENIE model, will also be present.

Thermal niche response of planktic foraminifera to the deglacial and anthropogenic warming

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Global warming is rapidly modifying the ocean environments but the plankton responses to the shifting climates are largely uncertain. Planktic foraminifera that own the most abundance microfossil data could provide the past insights for this question. Here, we combine a global trait-based foraminifera model and global foraminiferal abundance data to study their thermal niche evolution from the Last Glacial Maximum (LGM) to the next century. The results showed that symbiotic and spinose foraminifera shifted optimal temperature by 4 °C in the deglacial warming, while the symbiont-barren foraminifera (non-spinose or spinose) kept the same thermal niche and migrated poleward. However, when forcing the mechanistic model with rapid transient warming over the coming century, the model suggest that the thermal niche evolution of foraminifera is limited, particularly for the asymbiotic group. Under these conditions, planktic foraminifera are projected to migrate poleward with a declined global carbon biomass by 2.5-12.2% by 2100 relative to the present day (depending on warming scenario). Our model therefore highlights the different challenges posed by anthropogenic and deglacial warming on marine plankton which could cause irreversible marine biodiversity and ecosystem function loss in the future.

Nitrogen cycle perturbation during the Paleocene-Eocene Thermal Maximum

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Modern climate change is already negatively impacting the nitrogen cycle and ecosystem structure as a consequence of CO_2 emissions and warming. However, much less is known on the long-term impact of prolonged warming, acidification, and deoxygenation on the nitrogen cycle, which greatly affects the trophic state of the ocean. In this project we aim to study the nitrogen cycle perturbation during the Paleocene-Eocene Thermal Maximum (PETM), one of the best-studied analogs to inform on the future.
To elucidate changes in the nitrogen cycle during the PETM, we studied nitrogen cycle proxies such as nitrogen isotopes to describe the state of the nitrogen cycle and biomarkers to track specific nitrogen cycle processes. Samples were collected from equatorial Atlantic Ocean, Arctic Ocean, Tasman Sea, New Jersey shelf, North Atlantic and Eastern Tethys Ocean.
The biomarker results show an increase of anaerobic ammonia oxidation and nitrification processes in Arctic Ocean. This, combine with $\delta^{15}N_{bulk}$ data, indicates an anoxic environment and high nitrogen removal in the in the Arctic Ocean during PETM. However, the other sites show no obvious change in BHT-II ratio, although similar patterns of $\delta^{15}N_{bulk}$ have been observed. This indicates that nitrogen cycle perturbation varies within different ocean basins, anoxia exists in some but not all areas of the sea.
Our preliminary results indicate an enhanced nitrogen loss in coastal shelf areas and semi-enclosed basin during the PETM. This study shade light on understanding the ocean nutrient state in the background of global climate warming.