



P-001

## Centennial variability during the Medieval Climate Anomaly observed from North to South America

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*Predominance of drought conditions in WNA during the Medieval Climate Anomaly (MCA) has been related with La Niña like conditions, although other records from Eastern Tropical Pacific suggest a predominance of El Niño like conditions. Nevertheless, tree ring and lake precipitation records from Western North America show large centennial variability (~100-120 yrs cycles) during the MCA that bring alternation between wet and dry conditions. Here we show that paleoproductivity records from the southern domain of the California Current System also present large power spectra in the 100-120 yrs band that differs from the general view of constant El Niño or La Niña like conditions during the MCA. Furthermore, their relationship with the drought area index from WNA and Sea Surface Temperature from Makassar Strait suggest a ENSO-like variability of ~100 yrs periodicity. The analysis of high resolution records from North to South America indicates that, although the multicentennial variability dominates in most records, there is a secondary centennial cycle in some Central and South America records that broadly coincides with North America records. We discuss the hypothesis of a ENSO system with a dominance of SST anomalies located in the Central Pacific, instead of the canonical ENSO, to explain the relationships between those proxies that present this centennial variability.*



P-002

## A Pliocene-Pleistocene probabilistic stack of 180 globally distributed benthic $\delta^{18}O$ records

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*We collect globally distributed benthic  $\delta^{18}O$  records and combine them to construct one representative time series, called the Prob-stack, using a profile hidden Markov model. The benthic  $\delta^{18}O$  proxy represents the global nature of ice volume signal and deep water temperature. Thus, the stack provides better information than a single record can provide. Benthic stacks have been extensively employed as measures of global climate change and stratigraphic alignment targets found in age model developments or lead/lag relationship analysis. While there have been a large number of studies constructing a new benthic stack, algorithms for constructing a stack have been much less studied. Most algorithms determine alignments of benthic  $\delta^{18}O$  records deterministically without considering the uncertainty of alignments. To address this limitation, we develop a probabilistic stack which incorporates the variability among multiple records used to construct it and the uncertainty in alignments of records to the stack.*



P-003

## Can early warning signals be reliably detected in the Cenozoic palaeoclimate record?

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*Several episodes of rapid climate change and carbon cycle perturbations in Earth's history are hypothesised to be the result of the Earth system reaching a tipping point beyond which an abrupt transition to a new state occurs. These critical transitions are common in other complex dynamical systems and are often preceded in datasets by 'early warning signals' (EWS) such as critical slowing down and increasing variability. Dakos et al. [2008] and subsequent studies found that EWS can be detected prior to several past climate shifts, suggesting that critical transitions can successfully be detected in the palaeorecord. However, doubts have been raised about the reliability of EWS analysis on palaeoclimate records, the degree to which parameter selection can affect the results, and the risk of committing the 'prosecutor's fallacy' when analysing suspected critical transitions. Here we analyse the highest-resolution palaeorecords currently available across a number of Cenozoic carbon-climate system perturbations, including the Eocene-Oligocene Transition, mid-Miocene Climate Transition, and the Palaeocene-Eocene Thermal Maximum. We find that some but not all of the EWS indicators can be detected prior to these events, but that some results are highly dependent on parameter selection. Despite these problems our results appear to be relatively robust in most cases, and they reveal useful information about the behaviour of the Earth system prior to many Cenozoic carbon-climate system perturbations. As a result, this study illustrates how EWS analysis can be a useful tool in palaeoclimatology when used with sufficient caution.*



P-004

## Assessing the (a)synchronicity of climate signals in Shackleton site sedimentary records

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*The so-called "Shackleton sites" on the southwestern Iberian Margin have played a crucial role in the assessment of orbital- and millennial-timescale climate variability. Since Shackleton et al. [2000] discovered a tight correlation between sedimentary sequences from this margin and ice records from both Greenland and Antarctica, these sites emerged as a prime location to correlate ice-marine-continental climate signals. High sedimentation rates at the Shackleton sites also afford the opportunity to examine shorter-timescale (<100 yr resolution) climate variability throughout the last deglaciation and Holocene.*

*Many studies generate multi-proxy records at the same core site to constrain rapid climate variations, with chronostratigraphies being constructed from a singular age-depth model typically based on planktonic foraminiferal  $^{14}\text{C}$  dates. However, preliminary down-core measurements indicate significant and variable temporal offsets for carbon residing in different grain size fractions, and evidence suggests climate signals interpreted from disparate proxy signals, even derived from the same sediment core, might be aliased. For instance, compound-specific radiocarbon ages reveal differences of up to several thousand years between micro- (e.g., planktonic foraminifera) and molecular (e.g., alkenones) fossils within the same sediment layer. These age offsets have implications for interpretation of corresponding proxy records (e.g., foraminiferal- $\delta^{18}\text{O}$  versus alkenone-UK37' based sea surface temperature estimates).*

*Here, we attempt to quantitatively assess chronostratigraphic relationships among proxies and hydrodynamic influences on a sediment core from the benchmark Shackleton sites by developing independent, high-resolution  $^{14}\text{C}$  chronologies for planktonic foraminifera, coccoliths and alkenones.*

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P-005

## Early to middle Miocene climate evolution: benthic oxygen and carbon isotope records from Walvis Ridge Site 1264.

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*Here, we present the first early to middle Miocene high-resolution from the Atlantic basin, encompassing the Miocene Climatic Optimum (MCO) and the Mid Miocene Climate Transition (MMCT). These records, from Site 1264 on the Walvis Ridge, span a ~5.5 Myr long interval (13.24-18.90 ma) in high temporal resolution (~4 kyr) and are tuned to eccentricity. The  $\delta^{18}O$  record shows a sudden (high-latitude) warming/deglaciation on Antarctica at ~17.1 Ma, a rapid cooling/glaciation of Antarctica at ~13.8 Ma, and high-amplitude (~1‰) variability on astronomical time-scales throughout this interval. Together with other records from this time interval located in the Pacific, which show similar features, the data strongly suggests a highly dynamic global climate system. We find cooling steps in  $\delta^{18}O$  at 14.7, 14.2 and 13.8 Ma, suggesting concurrent cooling in the Pacific and Atlantic deep waters during the MMCT. The benthic foraminiferal stable isotope records reveal that the dominant astronomical frequencies present at ODP Site 1264 during the early to middle Miocene interval are the 405 kyr and ~110 kyr eccentricity periodicities. This is a contrast to other early to middle Miocene records from drill-sites in the Pacific and South China Sea, which show a strong expression of obliquity in particular between 14.2 and 14.7 Ma.*

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P-006

## Rates of East Antarctic Ice Sheet retreat during Plio-Pleistocene warm periods from detrital provenance analysis at IODP Site U1361

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*Marine-based sectors of the East Antarctic Ice Sheet (EAIS) have the potential to raise global sea level by around 20m. Whether such sectors could become unstable under a warming climate has recently been assessed using modelling approaches. Models of both past and future changes have shown significant Antarctic ice retreat with implications for predicted sea level given unabated emissions over the next few hundred to thousand years. Geological data from locations proximal to the EAIS are lacking, yet are needed in order to verify such rates of ice retreat under warmer conditions in the past.*

*Here we present geochemical provenance analyses (neodymium and strontium isotopes) on detrital sediments recovered during IODP Expedition 318 (Site U1361A), from the continental rise offshore of Wilkes Subglacial Basin. Our new study focuses on three warm intervals spanning the middle Pliocene to earliest Pleistocene, which are investigated at sub-orbital resolution to evaluate ice dynamics under warmer than modern temperatures.*

*Sediment provenance is shown to vary in parallel to ocean productivity in all intervals. Transitions into and out of individual warm phases occur gradually, and we tentatively suggest over timescales of a few millennia. For two of the three intervals investigated, these changes can be unambiguously tied to changes in the global benthic  $\delta^{18}O$  stack, and hence to ice volume. Our results are the first to provide geological support for suggested rates of ice retreat into East Antarctica's subglacial basins on the order of a few thousand years during Pliocene warm periods.*



P-007

## Marine radiocarbon simulations for the past 50000 years

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*We investigate marine radiocarbon distributions simulated for the past 50000 years using the ocean general circulation model LSG-HAMOCC2s. We explore various climatic background states, various atmospheric radiocarbon cycle boundary conditions, and spatially variable concentrations of dissolved inorganic carbon derived from marine carbon cycle simulations. Regarding the evolution of marine surface reservoir ages, our model reasonably agrees with glacial marine D14C records but indicates reservoir ages varying with time, different to the invariant reservoir age corrections typically applied to observations. Self-consistent simulations involving the Cariaco Basin record (which is the most continuous marine record contributing to the IntCal13 reconstruction for periods prior to about 30 kyears) amplify the temporal reservoir age variability and partly improve the agreement with measurements.*



P-008

## Timing of penultimate deglaciation captured in Iranian speleothem: Implications for glacial termination theory in the region and beyond

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*Speleothems' exceptional U/Th age model and high sampling resolution make these records ideal complements to paleocyanography studies. Particularly, a direct coupling between marine and speleothem records allows the transfer of the U/Th chronology, a feature essential to examining large climate shifts beyond the radiocarbon limits, such as the penultimate deglaciation (e.g. Cheng et al., 2006; Drysdale et al., 2009; Badertscher et al., 2011; Grant et al., 2012; Marino et al., 2015). The Iranian plateau's widespread karst topography and regional proximity to multiple isolated water sources sets the stage for such an investigation in this region. Although the area stands at the intersection of multiple large-scale climate systems, its climate history remains largely speculative due to limited accurately-dated paleoclimate records. Here we present the first Iranian speleothem record spanning a glacial termination. The stalagmite was collected in NE Iran (35.2°N, 57.4°E) and shows variable rates of vertical growth from 180-69 kyBP. Particularly slow growth is found from ~155-128 kyBP, though there is no geochemical evidence of a growth hiatus during this period. Notably, the record reveals a large (4‰) abrupt oxygen isotope shift toward more depleted values near 135kyBP, suggesting an association with the glacial termination. Several U/Th ages at high resolution are used to determine the precise and accurate timing of the oxygen isotope shift, and comparison with regional marine and speleothem records and model outputs is performed to infer the source of the large isotopic change.*



P-009

## The French initiative for scientific cores virtual curating : a user-oriented integrated approach.

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*Managing scientific data is a crucial issue for modern science. This concerns particularly the conservation of high value geological samples : cores. International scientific programs are leading an intense effort to solve this problem and propose detailed high standard work- and dataflows including core handling and curating. However, there is currently no consensual standard for sample and associated metadata management.*

*The national excellence equipment program CLIMCOR aims at developing French facilities for scientific coring (ice, marine and continental). As part of it, we led a reflexion about cores and associated metadata curating. Our aim is to conserve all metadata from fieldwork in an integrated cyber-environment which could evolve toward laboratory-acquired data storage. In that aim, our demarche was conducted through a close relationship with field operators and core curators, in order to propose user-oriented solutions.*

*The national core curating initiative currently proposes a single web portal to store field data. For forthcoming samples, we propose a mobile application to capture technical and scientific metadata on the field or in cruise.*

**12th International Conference on Paleocyanography**

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*This application is linked with a unique coring tools library and is adapted to most coring devices, including multiple sections and holes coring operations. Those field data can be uploaded automatically to the national portal, but also referenced through international standards or persistent identifiers (IGSN - SESAR, ORCID) and INSPIRE schema and displayed in international portals (currently, NOAA IMLGS).*

*In this paper, we present the architecture of the integrated system, future perspectives and the approach to reach our goals.*



P-010

## Evolution of the Tethyan circumglobal current during the Late Cretaceous: new insights from neodymium isotopes of carbonates and authigenic oxides from Iran (Zagros basin)

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*The Late Cretaceous period is marked by a long-term climatic cooling (Friedrich et al., 2012) and by major geodynamic changes, with modifications of the pole of rotation for the opening of the Atlantic (Guiraud and Bosworth, 1997). The African continent began a counterclockwise rotation during the Senonian, that is associated to the initiation of the Tethys ocean closure. Progressive restriction of the Tethys during this period may have modified the intensity of the Tethyan circumglobal current and led to the development of intense upwellings on the southern Tethyan margin, as suggested by the occurrence of large-scale phosphorite deposits on this margin, that peaks during the Campanian and Maastrichtian (Cook and Cook, 1985; Lucas and Prévôt-Lucas, 1995). In this study, we aim to better constrain the evolution of the Tethyan circumglobal current during these geodynamic changes that occurred during the Late Cretaceous. We focused on the Shahneshin section in the Zagros basin (Iran), that presents alternances marly-limestones deposited at upper-bathyal depths in the center of the Tethyan passage, from the Turonian to the Maastrichtian. We analysed the rare earth element spectra and neodymium isotope composition of marine carbonates and oxides leached from sediments of the section, and of the detrital fraction. The first results show a significantly more radiogenic Nd isotope composition of the carbonate and oxide fraction compared to that of the detrital fraction, by about 2  $\epsilon$ -units, that may at least partly reflect that of the local bottom waters in this region.*

**12th International Conference on Paleocyanography**

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P-011

## Efficacy of $^{230}\text{Th}$ normalization in sediments on the Juan de Fuca Ridge, northeast Pacific Ocean

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*$^{230}\text{Th}$  normalization is an indispensable method for reconstructing sedimentation rates and mass fluxes over time, but the validity of this approach has generated considerable debate in the paleoceanographic community.  $^{230}\text{Th}$  systematics have been challenged with regards to grain size bias, sediment composition ( $\text{CaCO}_3$ ), and water column advection. In this study, we investigate the consequences of these effects on  $^{230}\text{Th}$  normalization from a suite of six cores on the Juan de Fuca Ridge. The proximity of these cores (<30km) suggests that they should receive the same vertical rain rate of sediment, but the steep bathymetry of the ridge leads to substantial sediment redistribution and variable carbonate preservation, both of which may limit the usage of  $^{230}\text{Th}$  in this region. Despite anticipated complications,  $^{230}\text{Th}$  normalization effectively reconstructs nearly identical vertical sedimentation rates from all six cores, which are summarily unrelated to the total sedimentation rates as calculated from the age models. Instead the total sedimentation rates are controlled almost entirely by sediment focusing and winnowing, which are highly variable even over the short spatial scales investigated in this study. Furthermore, no feedbacks on  $^{230}\text{Th}$  systematics were detected as a consequence of sediment focusing, coarse fraction variability, or calcium carbonate content, supporting the robustness of the  $^{230}\text{Th}$  normalization technique.*



P-012

## Accurate orbital calibration of the late Miocene (8-6 Ma): perspective from a deep-sea chemo- and magnetostratigraphy

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*The late Tortonian-early Messinian (8-6 Ma) is characterised by a long-term reduction in benthic  $\delta^{18}O$  with distinctive short-term cycles. Coevally, the late Miocene carbon isotope shift (LMCIS) marks a permanent  $-1\%$  shift in oceanic  $\delta^{13}CDIC$ . Accurate age control is crucial to determine the origin of the  $\delta^{18}O$  cyclicity and the precise LMCIS duration.*

*The 8-6 Ma Geological Timescale (GTS2012) is based on astronomically tuned Mediterranean successions, which were used in the Rock-Clock synchronisation to adjust the Fish Canyon sanadine (FC)  $^{40}Ar/^{39}Ar$ -dating standard to  $28.201 \pm 0.046$  Ma. To test this synchronisation, the geomagnetic polarity timescale requires independent calibration outside the Mediterranean between 8-6 Ma. However, until now, no stand-alone deep-sea high-resolution chemo-, magneto-, and cyclostratigraphy existed.*

*We present new palaeomagnetic and benthic stable isotope data from equatorial Pacific IODP Site U1337 spanning 8-6 Ma. Fourteen polarity reversals are identified between  $C3r/C3An.1n$  ( $\sim 6.03$  Ma) and  $C4n.2n/C4r.1r$  ( $\sim 8.11$  Ma). Orbital tuning of the  $\sim 2$  kyr resolution stable isotope record shows exceptional obliquity-driven saw-tooth  $\delta^{18}O$  cycles, indicating predominantly high-latitude forcing. The LMCIS onset is tuned to  $7.590$  Ma (Chron  $C4n.1n$ ) and the termination to  $6.668$  Ma (Chron  $C3An.2n$ ). After astronomical calibration, the reversals change by 5-48 kyr relative to GTS2012. Key reversals  $C3An.2n/C3Ar$ ,  $C3Ar/C3Bn$  and  $C3Bn/C3Br$  are, respectively, 12, 48, 30 kyr younger, which implies a younger FC standard age.*



P-013

## 2000 years of annual precipitation variability in Southern California: Global forcing of ENSO variability

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*Controlled by Mediterranean climate, precipitation patterns in Southern California are strongly correlated with El Niño Southern Oscillation (ENSO) variability. Floods are generated by warm-wet storms; while droughts occur when North Pacific low pressure systems fail to reach the region. Winter precipitation delivers siliciclastic sediment to Santa Barbara Basin (SBB) via river runoff, whereas spring-summer upwelling produces biogenic sediment creating a simple two-component laminae couplet identified by bulk sediment geochemistry. These annual sediment changes are well preserved in SBB providing a continuous high resolution paleoclimate record.*

*Here we present scanning XRF generated annually resolved elemental variability for the last 2000 years in SBB from SPR0901-03KC. The first Principal Component (PC1) of the elemental data contains high loadings of Ti, K, Al, Si, Rb and Fe, and is associated with siliciclastic sediment. High PC1 scores are interpreted as increased river runoff, while low PC1 indicates decreased precipitation (droughts). According to PC1 scores, droughts were centered at 870, 970, 1140, 1300 and 1450 AD, during the Medieval Climate Anomaly, terminated by flood events at ~1270, 1380 and 1530 AD. Spectral analysis indicates that highest frequency peaks in PC1 are close to an annual resolution such that an annual band pass filter was applied to floating 100-year segments of the record to increase spectral resolution in the subdecadal spectra. Increased power in the subdecadal range is used to identify changes in the frequency and intensity of El Niño events during the last 2000 years in Southern California.*



P-014

## A Smoking gun for methane hydrate release during the Paleocene-Eocene Thermal Maximum

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*The Paleocene–Eocene Thermal Maximum (PETM; ~56 Ma) was a period of rapid 4–5°C global warming and a global negative carbon isotope excursion (CIE) of 3–4.5‰, signaling the input of at least 1500 Gt of  $\delta^{13}\text{C}$ -depleted carbon into the ocean-atmosphere system. Methane from submarine hydrates has long been proposed as the carbon source, but direct and indirect evidence is lacking. We generated a new high-resolution TEX86 and  $\delta^{13}\text{C}$  record from Ocean Drilling Program Site 959 in the eastern tropical Atlantic and find that initial warming preceded the PETM CIE by ~10 kyr. Moreover, time-shifted cross-correlations on these new and published temperature- $\delta^{13}\text{C}$  data imply that substantial (2–3 °C) warming lead  $^{13}\text{C}$ -depleted carbon injection by an average of 2–3 kyr globally. Finally, a data compilation shows that global burial fluxes of biogenic Ba approximately doubled across all depths of the ocean studied, which on PETM time scales can only be explained by significant Ba addition to the oceans. Submarine hydrates are Ba-rich and require warming to dissociate. The simplest explanation for the temperature lead and Ba addition to the ocean is that methane hydrate dissociated as a response to initial warming and acted as a positive carbon cycle feedback during the PETM.*



P-015

## The onset of the Paleocene Eocene Thermal Maximum: resolving millennial scale climate and carbon cycle interactions

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*The Paleocene Eocene Thermal Maximum (PETM; 56 Ma) is a short-lived episode of rapid global warming (>4 °C) associated with massive (>1500Gt) <sup>13</sup>C-depleted carbon release into the exogenic carbon pool. Changes in climate have been regionally found to lead <sup>13</sup>C-depleted carbon input by several millennia, suggesting a climatological trigger for the carbon release. However, millennial-scale variability across the onset of the PETM remains poorly resolved. In February 2016, we sampled a stratigraphically expanded uppermost Paleocene and PETM outcrop section near Princetown, Victoria, Australia. Our sampling strategy involved continuous recovery of the unconsolidated mudstones using steel casings. This allows for high-resolution X-ray fluorescence (XRF) scanning for bulk sediment chemistry, stable carbon isotope stratigraphy, grain size, TEX86 sea surface temperature reconstructions and dinocyst assemblages at sub-millennial temporal resolution. Preliminary results will be presented in the framework of local and global climate and carbon cycle evolution.*



P-016

## Sequence of events from the onset to the demise of the Last Interglacial: evaluating strengths and limitations of chronologies used in climatic archives

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*The Last Interglacial (LIG) represents an invaluable case study to investigate the response of components of the Earth system to polar warming. However, the scarcity of absolute age constraints in most archives leads to extensive use of various stratigraphic alignments to different reference chronologies. This feature sets limitations to the accuracy of the stratigraphic assignment of the climatic sequence of events across the globe during the LIG. Here, we review the strengths and limitations of the methods that are commonly used to define chronologies in various climatic archives (corals, speleothems, polar ice, marine and lake sediments) for the time span encompassing the penultimate deglaciation, the LIG and its demise (~140-100 ka). Recommendations are subsequently formulated on how best to define absolute and relative chronologies. Future climato-stratigraphic 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 underscore 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 comparisons with climate simulations. Finally, we provide a sequence of major climatic events with associated age uncertainties for the period 140-105 ka, which should serve as a new benchmark to disentangle mechanisms of the Earth system's response to orbital forcing and evaluate transient climate simulations.*

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P-017

## Insolation phasing of the North African monsoon and Mediterranean sapropels during the last glacial cycle

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*Precession minima are associated with an intensification and northward migration of the monsoon rainbelt over North Africa. The resulting increase in freshwater run-off from the North African margin into the Eastern Mediterranean led to deepwater stagnation and the preservation of organic rich layers (sapropels). Sapropels are therefore an excellent tool for establishing orbital chronologies, and for providing insights about longterm African monsoon variability. However, the link between precession minima, African monsoon 'maxima', and sapropel formation is not straightforward because different insolation phasings are observed between Holocene and early Pleistocene sapropels, and between proxy records and model simulations of the African monsoon. Here we use radiometrically-constrained, geochemical and ice-volume-corrected planktonic foraminiferal  $\delta^{18}O$  records from core LC21 (eastern Mediterranean) - with which the Red Sea sea-level record has been synchronised - to investigate the timing of African monsoon run-off and sapropels relative to insolation and ice-volume changes over the last glacial cycle. We find that the onset of monsoon run-off and sapropel deposition was near synchronous, yet insolation-monsoon phasings varied, whereby monsoon onset was relatively delayed (with respect to insolation maxima) only after glacial terminations. Given that we observe similar maximum rates of sea-level rise prior to monsoon onset, we suggest that it was the persistence of meltwater discharge into the North Atlantic over several kilo-years that delayed the timing of peak African monsoon run-off, and hence also the timing of the correlative sapropel. Our observed phasings reconcile model-data offsets.*



P-018

## Reconstructing surface water radiocarbon reservoir ages in the northeastern Atlantic Ocean.

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*Radiocarbon measurements from foraminifera in marine sediment cores are widely used to constrain age models and the timing of paleoceanographic events, as well as past changes in ocean circulation and carbon cycling. However, the use of radiocarbon for both dating and palaeoceanographic applications is limited in sediment cores by a lack of knowledge about the surface ocean radiocarbon reservoir age and how it varies in both space and time. Typically, to convert a planktic radiocarbon age into a calendar age, an assumed constant reservoir age is applied. However, there is mounting evidence to suggest that this assumption of constant reservoir age through time is an oversimplification, particularly for the high latitude oceans during the cold climates of the last glacial and deglacial periods. Here we present new high-resolution radiocarbon records together with tephra tie points and 230-thorium (230Th) constrained sedimentation rates to improve estimates of radiocarbon reservoir age in the Northeast Atlantic Ocean. In addition we will explore the impact of the new reservoir ages for both the age models of the cores studied, as well as the palaeoceanographic implications of these reservoir age changes during intervals of rapid climate change over the past 40,000 years.*



P-019

## Coral indicators of past sea-level change: a global repository of U-series dated benchmarks

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*Fossil corals provide valuable data for reconstructing past sea levels, as they are often well preserved in the fossil record and can be dated with U-series methods. Here we present a global and internally consistent database of U-Th dated fossil coral sea-level indicators, including full consideration of all (known) associated uncertainties (both vertical and chronological). This effort is needed to address current problems within Quaternary science (e.g. the relationship between sea level, ice sheets and changes in climate) which cannot be thoroughly addressed by looking at a single study, or a handful of studies, in isolation.*

*We include carefully determined taxon-specific depth distributions based on a synthesis of extensive modern ecological information on depth ranges. Additionally, our database contains extensive metadata to assist evaluations of dating quality, as well as geomorphic and stratigraphic context. We demonstrate with examples how such metadata can help to evaluate sea-level reconstructions. One example discusses the Last Interglacial (LIG), where we use the available data with their uncertainties to assess probabilistically the time at which local sea levels exceed that of the present. We also identify key outstanding issues relating to: (i) current incomplete understanding of tectonic setting (including the current lack of independent verification of uplift/subsidence rates and reliance of somewhat unsatisfactory, and circular, use of the elevation of Last Interglacial deposits); (ii) the depth-distributions of coral taxa and; (iii) the complete documentation of stratigraphic, geomorphological information and other contextual information.*



P-020

## Should Unit-stratotypes and Chronozones be formally defined? A proposal

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*The Global Stratotype Section and Point (GSSP) approach to define stage boundaries leaves the unit or body of the stage undefined. At the same time, arguments against the use of unit-stratotypes have been invalidated for the younger Cenozoic part of the geological record through the revolutionary advance in integrated high-resolution stratigraphy and astronomical dating. Combined these provide unprecedented age control and ensure continuity of sedimentary successions, at least within the time scales of the calibrated astronomical-forced climate oscillations, and offer the possibility to introduce amended unit-stratotypes for global stages. Here we propose that such unit-stratotypes should comprise the entire stage in an astronomically age calibrated deep-marine succession, preferably containing the GSSP. Cycles used for tuning can be formally defined as chronozones, i.e. chronostratigraphic units of either unspecified rank or of a smaller scale than the stage, and independent of the standard hierarchy in global chronostratigraphy. In this way, the standard Geological Time Scale and Global Chronostratigraphic Scale can be brought in line with the progress in integrated high-resolution stratigraphy and astronomical dating.*



P-021

## Deep ocean circulation across the deglaciation: radiocarbon and temperature from deep-sea corals and a dynamical box model

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*The circulation of Intermediate Waters influences global oceanic heat and carbon transport and changes in their distributions are also tied to glacial-interglacial climate transitions. In the modern ocean, temperature dominates interior density gradients and thus, to a large extent controls the deep circulation. Our chief tool for understanding the rate of this deep circulation comes from radiocarbon. Coupled radiocarbon and U/Th dates on deep-sea *Desmophyllum dianthus* corals allows for the reconstruction of past Intermediate Water circulation rates. Additionally, clumped isotope-based temperature estimates yield insight into the physical mechanisms contributing to the circulation variability. This information comes from the different boundary conditions for resetting temperature and radiocarbon at the ocean surface. In the modern Southern Ocean, temperature and radiocarbon are broadly correlated. Signals can be driven by changes in deep-water formation at high latitudes or by the extent of mixing between northern and southern-source waters at depth. These processes are in turn related to the interconnectedness of the overturning circulation.*

*We present a high-resolution time series of clumped isotope temperatures and radiocarbon measurements from Southern Ocean intermediate water (~1600m), derived from 27 corals spanning the LGM through the end of the ACR. Measurements from North Atlantic intermediate water deep-sea corals help constrain the mechanisms driving observed signals—in particular the bi-polar seesaw. We also use a time-dependent dynamic box model to test the sensitivity of the tracer variability to changes in surface forcing and physical characteristics of the overturning circulation.*



P-022

## Radiocarbon chronology of the last deglaciation in the Baffin Bay reveals asynchronous melting of North American ice sheets

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*The transition from the last ice age to the current Holocene warm period was characterised by the retreat of the North American ice sheets, delivering large quantities of meltwater into the Labrador Sea. Whereas the meltwater chronology of the Laurentide Ice Sheet is well documented, the late and post-glacial history of the Innuitian and Northern Greenland Ice Sheets draining into the Labrador Sea via the Baffin Bay is less well constrained. We present a new high-resolution and radiocarbon-dated chronology from the Canadian and Greenland margins of the southern central Baffin Bay. Sedimentological and geochemical data confirm the presence of two intervals of enhanced detrital carbonate (Baffin Bay Detrital Carbonate Events) delivery during Termination 1. These events are synchronous across the Baffin Bay and we refine their timing to between 14.2 – 13.7 kyr BP and 12.7 – 11.2 kyr BP. Their mineralogical composition indicates a Canadian Arctic detrital carbonate source as well as a clastic source proximal to Greenland. These events post-date Heinrich events documented in the Labrador Sea and their onset is not linked with Greenland temperature change, indicating that the deglaciation of American Arctic ice sheets and associated meltwater discharge were decoupled from the dominant North Atlantic climate mode. Furthermore, we use micropaleontological proxies, included planktic and benthic foraminifera  $\delta^{18}O$ , benthic  $\delta^{13}C$  and benthic assemblages to ascertain whether changes in surface and/or bottom water in the Baffin Bay were a precursor or product of these events during the deglaciation.*



P-023

## Temporal coupling of terrestrial detrital flux and the Carbon Isotope Excursion through the Paleocene-Eocene Thermal Maximum

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Quantifying and understanding the prevalence of non-linear dynamics across major climate transitions is a fundamental challenge to climate science. The Paleocene-Eocene Thermal Maximum (PETM; ~56 Ma) is a large but transient, greenhouse gas-driven warming event. The magnitude of the PETM global temperature anomaly of 4-5°C, associated with at least a doubling of atmospheric pCO<sub>2</sub>, is similar to future emissions scenarios and climate projections for the 21st Century. Recent data constrain the duration of the PETM onset to within a few millennia, driven by a rapid release of reduced carbon to the ocean-atmosphere system. Here we present new high-resolution records of the PETM Carbon Isotope Excursion (CIE), as well as detrital sediment flux data as a proxy for terrestrial hydroclimates, from a complete continental slope section. Set within a new cyclostratigraphic framework for the entire PETM interval, these confirm the rapid onset of the PETM followed by a plateau phase. They also demonstrate the coupled recovery in both the CIE and the rates of continental erosion over ~10ka. This strong coupling between carbon flux and terrestrial hydroclimates, with a rapid onset (~1-2 ka) and recovery (<10 ka) in both, indicates the presence of carbon release and sequestration mechanisms capable of generating distinct non-linear bistability in ancient warm climate states.

**12th International Conference on Paleooceanography**  
29 August – 2 September 2016, Utrecht, the Netherlands



P-024

## Eccentricity-paced Pacific carbonate dissolution cycles during the Miocene Climatic Optimum

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*The coupling of global warming and shoaling of the carbonate compensation depth (CCD) during the Miocene Climatic Optimum (MCO) is still poorly resolved. We present new high-resolution benthic stable oxygen ( $\delta^{18}O$ ) and carbon ( $\delta^{13}C$ ) isotope records over the late early to middle Miocene interval (18 to 13 Ma) at Integrated Ocean Drilling Program (IODP) Site U1335 in the eastern equatorial Pacific and integrate these data with stable isotope and X-ray fluorescence (XRF)-scanner derived carbonate content records published for IODP Sites U1335, U1336, U1337 and U1338. Stable isotope records at Site U1335 depict the onset and development of the MCO, followed by the transitional climatic phase that leads to global cooling at 13.8 Ma. At sites located on older oceanic crust and distant from the equatorial high-productivity zone (U1335, U1336 and U1337), peaks in carbonate dissolution (decreasing carbonate content by ~60%) coincide with low  $\delta^{18}O$  and  $\delta^{13}C$  values and occur during periods of high orbital eccentricity (100 kyr variability) during the MCO. Taking into account backtracked paleo-depths for these sites in relation to Site U1338, which was located on younger crust and less affected by carbonate dissolution, we estimate that lysocline shoalings were in the order of 0.5 km. The eccentricity-paced co-variance of  $\delta^{18}O$  and  $\delta^{13}C$  during the MCO, with low values coupled with significant drops in carbonate content, points to climate-carbon cycle feedbacks that show no resemblance to glacial-interglacial patterns, but are closer to variability reported for Paleogene hyperthermals.*



P-025

## Is there a similarity between the last two glacial terminations? Insights from Western Equatorial Africa.

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*Abrupt changes in the African monsoon can have prominent socioeconomic impacts for many West African countries. Evidence for both prolonged humid periods and drought intervals, driven by rapid fluctuations in the monsoon system, have been identified throughout the Quaternary record. Glacial terminations specifically evidence rapid climate transitions and involved rapid, non-linear reactions of ice volume, CO<sub>2</sub> and temperature to external astronomical forcing. The last deglaciation into the Holocene (Termination 1) is well documented in both hemispheres. The penultimate deglaciation of stage 5 (Termination 2) is not, and the precise timing of this event, as well as hemispheric response, is still unclear.*

*Changes in the strength of the West African Monsoon reflect the complex interaction between low latitude solar insolation and high latitude ocean circulation. Marine sediment sequences offer high-resolution, uninterrupted records of palaeoclimatic change and the opportunity to further explore the drivers behind WAM variability. Here we present a continuous marine sediment record from the Ogooué Fan, Gabon, covering the last 152,000 thousands years. Geochemical and total organic carbon records evidence pronounced terrigenous outwash from the Ogooué River, and a concomitant strengthening of the WAM, during Termination 2 that is not present during the Termination 1. Further, isotopic  $\delta^{18}O$  and  $\delta^{13}C$  sequences yielded foraminifera conversely evidence a weakening of the monsoon into the Holocene and document an increase in oceanic productivity and regional upwelling.*



P-026

## WAVEPAL: A Software for Wavelet Analysis of Irregularly Sampled Time Series

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Wavelet analysis is often used to analyze time-varying periodicities in paleoclimate time series. However, the quasi-totality of existing wavelet softwares require the data to be interpolated on a regular grid. This leads to biases, especially for significance testing. The few softwares that do not require interpolation come from astronomy and astrophysics fields, but they make hypotheses that are not suitable in paleoclimatology. The poster will present a software which does not require the data to be interpolated and which is relevant for paleo-data. It is based on a rigorous mathematical approach: we extend the Lomb-Scargle periodogram to the Morlet wavelet case. Moreover, significance testing against some type of noise (for example, a red noise) needs some coefficients to be estimated. Our software takes into account the uncertainty on those coefficients, based on Bayesian statistics. It thus provides very reliable confidence levels, in order to extract the « not-due-to-noise » part of the signal. The latter may be filtered with different kinds of filters proposed in the software. Finally, like the periodogram, the wavelet transform suffers from not being a consistent estimator of the true spectrum. Smoothing the wavelet transform can fix this issue, and this option is also available in the software.



P-027

## What is the future of stacking?

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*The development and application of benthic  $d_{18}O$  stacks has always been accompanied by the caveat that ocean mixing times limit the synchronicity of benthic  $d_{18}O$  changes. However, the utility of a stack age model is now challenged by demands for age estimates that are accurate enough to investigate millennial-scale processes and by extensive evidence that the timing of benthic  $d_{18}O$  change varied by as much as 4 kyr during the last deglaciation. Such large spatio-temporal variability could also affect other portions of the glacial cycle if deep water masses experience different histories of temperature or salinity change. The impacts of such limitations on benthic  $d_{18}O$  stacks can be mitigated using several strategies, including: the development of regional stacks, comparison of multiple radiometric and stratigraphic dating techniques, better uncertainty quantification, and the incorporation of insights from models of orbital and millennial-scale circulation changes. Finally, I will discuss the appropriate interpretations and applications for benthic  $d_{18}O$  stacks given the limitations imposed by heterogeneous  $d_{18}O$  signals.*



P-028

## Multi-proxy reconstruction of time scale for Site MD01-2414 in the Okhotsk Sea, northwestern subarctic Pacific Ocean

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We reconstructed a multi-proxy (XRF-scanning, radiocarbon dates, magnetic reversals and susceptibility, biostratigraphy, and diatom abundance) time scale for Site MD01-2414 (53°11.77'N, 149°34.80'E, water depth 1123 m) in the Okhotsk Sea, northwestern subarctic Pacific Ocean. Okhotsk Sea is the southern most seasonal sea ice distributed region in the Northern Hemisphere. Due to the lack of continuous carbonate microfossil preservation, it was very difficult to reconstruct reliable age model in the past. By using XRF scanning for 52.73-m sediment column,  $\log(\text{Ba}/\text{Ti})$  was used to correlated to LR04 record to produce age model back to ~1.56 Ma.

Biological productivity is higher during the interglacial periods in the Okhotsk Sea which has been supported by higher  $\log(\text{Ba}/\text{Ti})$  ratio, diatom abundance, and lower magnetic susceptibility through all glacial/interglacial (G/IG) cycles during the past 1.56 Ma. Exception high productivity periods occurred during the marine isotope stage (MIS) 1, 5, 9, 11, 25, 31, 37, 47, and 49. Long term biological productivity shows step-wise decreasing trend. First significant drop occurred in MIS 26 and then followed by MIS 23 during the Mid-Pleistocene Transition (MPT) around 0.9 Ma.



*This time scale is the first one in the Okhotsk Sea that can fully capture the G/IG periodicities changes during MPT. Reliable multi-proxy constrained age model shall provide a solid foundation for the future sea ice and ocean circulation studies in this climate sensitive region.*

**12th International Conference on Paleoceanography**  
29 August – 2 September 2016, Utrecht, the Netherlands



P-029

## **87Sr/86Sr as a quantitative geochemical proxy for 14C reservoir age in dynamic, brackish waters: Assessing applicability and quantifying uncertainties.**

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*Accurate geochronologies are crucial for reconstructing the sensitivity of brackish and estuarine environments to dynamic external impacts of the past. Radiocarbon ( $^{14}\text{C}$ ) dating is commonly used for palaeoclimate studies, but its application in brackish environments is severely limited by an inability to quantify spatiotemporal variations in  $^{14}\text{C}$  reservoir age, or  $R(t)$ , due to dynamic interplay between river runoff and marine water. Additionally, old carbon effects and species-specific behavioral processes also influence  $^{14}\text{C}$  ages. Using the world's largest brackish water body (the estuarine Baltic Sea) as a test bed, combined with a comprehensive approach that objectively excludes both old carbon (using GIS) and species-specific  $^{14}\text{C}$  effects, we demonstrate the use of  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios for quantifying  $R(t)$  in ubiquitous mollusc shell material, leading to almost an order of magnitude increase in Baltic Sea  $^{14}\text{C}$  geochronological precision over the current state of the art. We propose that similar proxy methods can be developed for other brackish water bodies worldwide.*



P-030

## Potential and limitations of Mn stratigraphy as a chronostratigraphic tool in the Arctic Ocean

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*One major obstacle when studying Arctic paleoceanography is age control. Not only have severe ice conditions during glacial intervals resulted in a near complete lack of micro- and nannofossils, but corrosive pore- and bottom waters have removed much of the calcareous microfossils deposited during interglacial periods too. Moreover, the strong riverine input during interglacial periods effectively mask any temperature or ice volume signal, making correlations to low-latitude isotope records complicated. Age models for Arctic archives therefore typically are built on a mosaic of various age control points based on biostratigraphic markers, lithological and geochemical correlations, and age points obtained through radiocarbon dating, paleomagnetic methods, or OSL. Correlations between cores are based on the assumption that glacial and interglacial intervals will be clearly distinguishable and that any hiatuses can be identified. If these criteria are not fulfilled, then downwards propagating offsets between different records will be introduced, making any paleoceanographic reconstructions pointless. Using radiocarbon dating on a number of cores primarily from the central Arctic and the Fram Strait region, we here demonstrate that in many cores, the MIS 2 is so weakly developed that the interglacial Mn peaks related to MIS 3 and MIS 1 appears as one continuous interglacial. However, through careful observations of Mn, Ca, foraminifer abundance variations and changes in the ice rafted debris content of the sediment, independent criteria for the identification of missing glacial intervals can be developed. Recognition of these intervals is essential for our ability to correlate sedimentary archives across the Arctic.*



P-031

## Monsoon variability in the northeastern Arabian Sea on orbital- and millennial scale during the past 225,000 years

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*The Dansgaard-Oeschger oscillations described in the Greenland ice cores are expressed in the climate of the tropics as documented in Arabian Sea sediments. However, little is known about these fluctuations beyond the reach of the Greenland ice cores. Here, we present high-resolution geochemical and micropaleontological data from two cores off the coast of Pakistan, extending the monsoon record to the past 225,000 years.*

*The stable oxygen isotope record of *G. ruber* shows a strong correspondence to Greenland ice core data, whereas the deepwater signal of benthic foraminifera reflects patterns recorded in ice cores from Antarctica. Shifts in the benthic record during stadials/Heinrich events are interpreted to show frequent advances of oxygen-rich intermediate water masses into the Arabian Sea originating from the southern ocean. Alkenone-derived SSTs varied between 23 and 28°C. Rapid SST changes on millennial scale are overlain by long-term SST fluctuations. Interstadial data show that enhanced fluxes of terrestrial-derived sediments are paralleled by productivity maxima. Stadials are characterized by an increased contribution of aeolian dust. Heinrich events are especially dry events, indicating a dramatically weakened Indian summer monsoon.*

*These results strengthen the evidence that North Atlantic temperature changes and shifts on the hydrological cycle of the Indian monsoon system are closely coupled, and had a massive impact on regional environmental conditions such as river discharge and ocean margin anoxia. These shifts in the surface and sub-surface ocean were modulated by changes in the supply of water masses from the southern hemisphere.*



P-032

## South East African precipitation over the last 30kyr

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*African continental climate changed substantially over the last 30kyr. Of particular interest is the temporal and spatial variation of evaporation-precipitation (E-P) balance related to climate change in the high latitudes. Existing records suggest large shifts in precipitation distribution across Africa during the early Holocene African Humid Period. Changes in the average position and overall annual range of the inter-tropical convergence zone (ITCZ) control rainfall distributions in the region. Although most existing records broadly support the idea of a wet Early Holocene in Africa, the temporal and spatial heterogeneity is poorly understood.*

*We present geochemistry data from a depth transect of three sediment cores retrieved offshore Tanzania (~9°S). Independently developed, radiocarbon based, chronologies allow placement of these records in the context of African rainfall variations. Our data reflects precipitation changes over the relatively small Rufiji river catchment. The latitudinal range of this catchment is similar to the northern part of the larger Zambezi catchment and is also comparable to much of the Congo catchment. This provides excellent scope for placing our data in a larger context aimed at assessing ITCZ shifts in Africa.*

*Our initial analysis suggests notable E-P balance variability at the millennial scale, with a significant wetting commencing after Heinrich event 1 at ~16kaBP. Wet conditions peaked at ~10kaBP. More arid conditions prevailed later during the Holocene.*

*Continued work looks to place these new records fully in context and help contribute to our understanding of climate variability in Africa over the last 30kyr.*



P-033

## How the Antarctic Circumpolar Current (ACC) and the Austral ocean have varied in the Kerguelen sector during the deglaciation and the last climatic cycles

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*IndienSud-1 and 2 expeditions aboard the RV Marion-Dufresne were conducted in 2011 and 2012 in the Kerguelen sector of the South Indian Ocean. Objective was to obtain Casq and Calypso cores documenting past ocean changes, in particular that of the Antarctic Circumpolar Current (ACC), during the last climatic cycles, with a focus on the last deglaciation.*

*For the long-term, results document a stronger ACC during glacial than during interglacial periods for at least the past 600 kyr. This pattern is opposite to that of the NADW branch (WBUC) south of Greenland. These observations highlight an antiphase pattern between ACC and NADW on orbital timescales.*

*For the past 25 000 years, high-resolution multiproxies records were obtained at two sites along the main branch of the ACC. Changes in the ACC intensity are investigated using environmental magnetism methods tracing both the amount and size of sedimentary magnetic grains. In addition, oxygen isotopes and foraminifera faunal assemblages trace hydrological and temperature changes. A precise age scale is derived from  $^{14}\text{C}$  ages determinations, complemented by regional correlations (magnetic susceptibility) to other  $^{14}\text{C}$  dated cores in the same area. During the last deglaciation, temperature increased prior to a marked decrease in the ACC intensity. It could be associated to the rate changes of the AMOC and to deep ocean ventilation. These changes appear to be closely connected to atmospheric  $\text{CO}_2$  changes during the last deglaciation.*

*This study is funded by the INSU-LEFE program DYNACC and by a French-Swedish program.*

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P-034

## Timing of Southern Ocean upwelling changes in the Pacific and Indian sector during the last deglaciation, a contrasted evolution with the ACC in the Indian sector.

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*The Southern Ocean plays a central role in ocean-atmosphere exchange of heat and CO<sub>2</sub>, through the upwelling of deep waters driven by the westerly winds and the Coriolis force. During the last deglaciation wide reorganization of the deep ocean circulation took place and the atmospheric carbon dioxide content increased by more than 30%. Here we compare new records from the Indian sector of the Southern Ocean with records from the Pacific SE sector to evaluate the timing of Southern Ocean upwelling changes during the last deglaciation. The cores were retrieved during Pachiderme and Indien-Sud cruises, supported by IPEV logistics. We present benthic and planktonic foraminifera carbon isotopes records to record upwelling variations and compare them to the sea surface temperature evolution as reconstructed by planktonic foraminifera assemblages. Temperature increase (decrease) is coeval with upwelling increase (decrease). Taking into account the large chronological uncertainties inherent to oceanic sediment records of the Southern Ocean, we discuss the timing of these events with the bipolar see-saw related rapid changes, as indicated by isotope records of ice core.*

*The ACC variations in the Indian Ocean sector indicate a different evolution than the Southern Ocean upwelling variations. While the upwelling changes seems to be mainly linked to westerlies position/intensity changes, the ACC modulation could be tied to other factors like density changes across the Southern Ocean.*



P-035

## **Orbital climate control of coal formation during the early Paleocene of northeastern Montana: implications for the global carbon cycle**

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*Extensive coal deposition in sizable sedimentary basins could be a major sink for atmospheric CO<sub>2</sub> in the global carbon cycle. Quantification and timing of carbon fixation in past coal formation are key to investigate the role of extensive peat-forming environments during current global warming. However, reliable estimates of both quantification and duration of coal deposition are challenging as both strongly depend on the forcing mechanism that controlled sedimentation. Dominance of autogenic, base level, and/or tectonic forcing results in discontinuous and diachronous coal beds complicating carbon estimations. If orbital climate forcing is the dominant forcing mechanism better predictions will be possible as this affects large areas and occurs over regular, predictable periods of time. Our results suggest that lower Paleocene coals of the Lower Fort Union Group in the Western Interior Williston Basin were probably driven by orbital climate change. We come to this conclusion by high-resolution <sup>40</sup>Ar/<sup>39</sup>Ar radio-isotope and magnetostratigraphic age control on regular coal alternations that are well exposed in the badlands of northeastern Montana (USA).*



P-036

## Determining sedimentation rate uncertainty in a highly expanded Late Glacial - Holocene sediment sequence recovered from the deepest Baltic Sea basin – IODP Site M0063

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*Laminated, organic-rich silts and clays with high dissolved gas content characterize sediments at IODP Site M0063 in the Landsort Deep, which at 459 m is the deepest basin in the Baltic Sea. Cores recovered from Hole M0063A experienced extreme expansion during the recovery process, resulting in significant sediment loss. Therefore during operations at the subsequent four holes, penetration was reduced to 2 m per 3.3 m coring run, permitting expansion into 1.3 m of initially empty liner. Average recovery for Holes B through E was in excess of 99%, indicating that the length of each recovered interval exceeded the penetrated distance by a factor of >1.5.*

*We note a typical logarithmic trend in the down-core gamma density profiles, with anomalously low values within the upper ~1 m of each core. We interpret that expansion primarily occurred in this upper interval and suggest that a simple linear correction is inappropriate. Based on the mean gamma density profiles of cores from Holes M0063C and D, we obtain an expansion function that is used to adjust the depth of each core to conform to a 2-m penetration. The variance in these profiles allows for quantification of uncertainty in the adjusted depth scale. Together with a number of bulk <sup>14</sup>C dates, we explore how the presence of multiple carbon source pathways leads to poorly constrained variations in radiocarbon reservoir age, which significantly affects age and sedimentation rate calculations.*



P-037

## Investigating orbital controls on Late Cretaceous climate

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*Cyclic patterns in sedimentation and geochemistry are well known from the geological record and have long been hypothesised to be the consequence of orbitally-forced climate change. However, during periods of greenhouse climate, the mechanisms by which changes in insolation are amplified by the Earth system remain poorly understood. Many records from the Late Mesozoic greenhouse world suggest orbital forcing of the carbon cycle, which may have driven changes in atmospheric CO<sub>2</sub> and climate. We seek to test this idea through a multi-proxy reconstruction of mid-latitude climate and environmental variability during the Campanian, with the aim of identifying a climatic link between orbital periodicities and the sedimentary record.*

*The Shuqualak-Evans borehole, Mississippi (USA), provides a Campanian (Late Cretaceous) record of hemipelagic shelf sedimentation deposited at a palaeolatitude of ~35°N. The existing age model suggests a deposition rate of ~2.8cm/kyr, thereby permitting sampling of this core at sufficient resolution to capture orbital periodicities. Unfortunately, core recovery and preservation only permits continuous sampling in two discrete ~15m thick intervals. These intervals show cyclicity in TOC and %CaCO<sub>3</sub>, which spectral analysis suggests is consistent with orbital frequencies.*

*The Shuqualak-Evans core is very suitable for palaeoenvironmental analysis using a range of inorganic ( $\delta^{13}C$ ,  $\delta^{18}O$ , major and trace element ratios) and organic proxies. For example, previous work on this core used TEX<sub>86</sub> to yield a long-term SST record. We will present the initial results of our palaeoclimatic and palaeoenvironmental reconstruction and discuss the relationships with orbital forcing.*



P-038

## The role of thermal threshold of the Atlantic meridional overturning circulation in glacial abrupt climate changes

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*Abrupt climate changes known as Dansgaard-Oeschger events (DO events) took place frequently in glacial periods. Geological evidences support the idea that changes of the Atlantic meridional overturning circulation (AMOC) are related to these events, but question on what triggers the AMOC changes remains unsolved. Although the most of studies have regarded freshwater flux from melting ice sheet as a cause of the AMOC changes, here we report the importance of the thermal threshold of AMOC (Oka et al., 2012) for explaining the abrupt strengthening of the AMOC. We investigated the structure of the thermal threshold in glacial climate by conducting ocean general circulation model simulations under various thermal conditions in which degrees of sea surface cooling are systematically changed separately or simultaneously in northern and southern hemispheres. The results suggest that the threshold is located near the condition in which the climate is slightly warmer than the coldest glacial conditions. We found that the amplitude of AMOC changes in crossing this threshold depends on thermal conditions in northern and southern hemispheres. This amplitude becomes the largest when the southern hemisphere is slightly warmer than the coldest glacial conditions. It is also demonstrated that gradual warming in the southern hemisphere from the colder glacial climate leads to crossing the threshold and can cause very large strengthening of AMOC. The existence of the thermal threshold successfully explains the abrupt strengthening of the AMOC during glacial climate, suggesting that it is a important factor for explaining mechanism of DO events.*



P-039

## Glacial-Holocene changes in radiocarbon reservoir ages in the western North Pacific off Japan

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*Constraint on radiocarbon marine reservoir age is important for dating of marine samples and understanding oceanic carbon cycle for the past 50 kyrs. Tephrochronology is a potential tool for evaluating past regional marine reservoir ages. In and around Japan, numbers of volcanic eruptions have been recorded including several mega eruptions since the last glacial period. These tephra ages have been well determined based on terrestrial records including varved sediments in the Lake Suigetsu. We have collected marine core samples from the NW Pacific around Japan and subsampled tephra layers and sediments directly above and beneath of the tephra layers. Four tephra layers at 7.2 ka, 15 ka, 19 ka and 30 ka were identified based on volcanic glass analyses. Glacial-Holocene marine reservoir ages ( $R$ ) in NW Pacific off Japan were estimated by comparing tephra ages with foraminiferal  $^{14}\text{C}$  ages at the tephra layer in marine sediments. Our reconstructed marine reservoir ages were not very old but almost comparable to the pre-bomb values even during LGM and deglaciation.*



P-040

## Abrupt change in the ocean surface conditions in Baffin Bay at the end of deglaciation

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We present here the first high resolution reconstructions of August sea surface temperatures (aSST) and April sea ice concentrations (aSIC) from Baffin Bay covering the deglacial period. Baffin Bay is climatically sensitive area, since it is influenced by the cold Baffin Current and the warmer West Greenland Current, and has a close link between the ocean circulation and ice sheet dynamics. Reconstructions were made using diatom assemblages in two marine sediment cores, SL-170 and SL-174, recovered from central Baffin Bay and close to Baffin Island, respectively. Diatom data was converted into aSST and aSIC by using a calibration dataset (Miettinen et al. 2015) and a weighted averaging partial least squares WA-PLS transfer function (Ter Braak and Juggins 1993). Different age models (Clam, BACON, Bchron, OxCal) are currently tested to create the most accurate age models for the cores. Despite the yet uncompleted chronologies, we conclude that the studied time interval falls into deglaciation from ca. 10 to 15 cal ka BP and that an abrupt change took place in diatom assemblages during the transition from the deglaciation to the onset of the Holocene. During this change aSIC decreased rapidly and the inflow shifted from the Arctic waters to Atlantic waters for ca. 500 years. This shift could be linked to the enhancement of the Atlantic Meridional Overturning Circulation (AMOC).

Miettinen et al. 2015. *Paleoceanography* 30, doi:10.1002/2015PA002849.

Ter Braak & Juggins 1993. *Hydrobiologia* 269–270, 485–502.



P-041

## Early Pleistocene changes in tropical climate conditions and hominin evolution

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*Detailed analysis of both lithogenic and biogenic components from the Eastern Equatorial Pacific (EEP) ODP Site 1240 reveals the occurrence of major changes in the position/intensity of the Intertropical Convergence Zone (ITCZ) during the early Pleistocene. Both upwelling and wind proxies suggest coupled changes in the tropical ocean-atmosphere system whose remote implications are here evaluated through the comparison of the EEP records with other marine and terrestrial records from the tropical/subtropical belt. In particular, we have selected terrigenous records from the equatorial Atlantic Ocean, the Arabian Sea and the Chinese Loess. All these records indicate that, prior to 1.85 Ma, ITCZ had a dominant southern position, as shown by radiogenic isotopes, which would have resulted in increased precipitation along tropical and subtropical regions. After 1.85 Ma, records signal a northward shift of the ITCZ, which would have reduced rainfall at the studied locations. Interestingly, new chronologies from South Africa speleothems (cave carbonates) reveal the occurrence of a series of humid episodes, which seem also associated with a minimum in eccentricity that ended around 1.8 Ma. The described changes in the ITCZ are thus consistent with the enhanced aridity in the African continent that triggered a gradual vegetation change, apparently linked to the evolution from *Homo habilis* to *Homo erectus*. New South African chronologies allow to precisely locating some hominin evolution events within the paleoclimate record and they support the notion that some ancestors did not survive this major ITCZ early Pleistocene transition.*



P-042

## Expanding the NSB (Neptune) Database for use in paleoceanography

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*The Neptune database was originally created in the 1990s to hold deep-sea drilling marine microfossil occurrence data, linked to numeric ages for samples via age models for each section. This version has been used in numerous micropaleontological studies, mostly on evolution. With funding support from CEES and the ESF/Earthtime-EU, a new, expanded version with extensions for paleoceanography has now been created (Neptune Sandbox Berlin, NSB: [www.nsb-mfn-berlin.de](http://www.nsb-mfn-berlin.de)). A new stratigraphic data layer has been added, incorporating 27k+ biostratigraphic and magnetostratigraphic events used to create the age models, together with nearly 2k event definitions and calibrations. Important newer ODP and IODP sections have been added (>400 Holes in total) and the age scale updated to Gradstein et al. 2012. In order to make effective use of these geochronologic extensions a new open source implementation of the Age-Depth Plot program has been developed. Occurrence data has also been enhanced (nearly doubled to 800k) and the taxonomy thoroughly overhauled, based on IODP's Taxonomic Name List project. Geographic discrimination will soon be improved by addition of Longhurst planktonic biome classification and backtracked paleocoordinates for each site. These additions to NSB provide an improved platform for global syntheses of deep-sea drilling data not only in marine micropaleontology but also in paleoceanography.*



P-043

## Bartonian bioevents and paleoenvironments: new foraminiferal data from the SW Tethys

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*The International Subcommittee on Paleogene Stratigraphy is searching for an appropriate section to define the GSSP (Global Stratotype Section and Point) for the base of the Bartonian Stage (Eocene). The Bartonian stage was originally defined in the Hampshire Basin (UK), where a bed containing abundant tests of the macrobenthic foraminifer *Nummulites prestwichianus* has been traditionally used as a biostratigraphic marker to define the base of the Bartonian. This criterion, however, is not suitable for global correlation given the limited distribution of this bed, which is close to the first occurrence of the dinocyst *Rhombodinium draco*. Magnetostratigraphy offers global criteria that are more suitable for correlation, but it needs calibration with e.g. biostratigraphic markers.*

*Here we present new micropaleontological data from Torre Cardela section (Southern Spain, SW Tethys), where the Bartonian is well exposed over a 80-m-thick interval. This section was deposited at middle to lower bathyal paleodepths, and contains more cosmopolitan taxa (i.e., more suitable for global correlation) than the shallower deposits in the classical Barton area. Benthic foraminiferal assemblages contain abundant *Bolivinooides* and *Bolivinia* species among infaunal morphogroups, and *Asterigerina* and *Cibicides* species among epifaunal ones. Analysis of the benthic foraminiferal turnover allowed us to infer a sequence of paleoenvironmental changes close to the base of the Bartonian (as indicated by planktic foraminiferal biozones), which may be useful for correlation with other locations, and may contribute to the definition of the GSSP for the base of the Bartonian.*



P-044

## Microfossil evidence of the starved-shelf to river-dominated ecosystem transition at the Paleocene-Eocene Thermal Maximum onset at Mattawoman Creek, Maryland (USA)

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*The Paleocene-Eocene Thermal Maximum (PETM; ~55.5 Ma) was a period of extreme global warmth and rapid climate change resulting from a quick and massive release of carbon into the atmosphere and oceans. The PETM is identified by a -3 to -8‰ carbon isotope excursion (CIE) in deep sea cores where sediment accumulation rates are low and calcareous microfossils have been removed due to ocean acidification, and in terrestrial sections where continuous time series data are rare. Only shallow marine cores above the lysocline and with higher sediment accumulation rates allow us to identify changes in both marine ecology and terrestrial climate during this transition. Several shallow marine cores along the east coast of North America have been studied for this purpose. At Mattawoman Creek, Maryland, we recovered 8.2m of sediment containing latest Paleocene and earliest Eocene transitional fauna and flora that elsewhere along the coastal plain are restricted to <1m.  $\delta^{13}C$  values obtained from the benthic foraminifer *Bulimina virginiana* record a -2.8‰ excursion over 2m, whereas the onset spans <0.5m at other sites. Planktic and benthic foraminifera, calcareous nannofossils, and palynomorphs record ecological changes at this site in detail showing a transition from a sediment-starved shelf to the development of periodic river outflow to a dysoxic, river-dominated system. We estimate this transition occurred over 17-23 kyrs with a sediment accumulation rate of 36-50 cm/kyr. Because the top of the PETM is missing, these estimates are difficult to further refine.*



P-045

## Evidence of the 1,500 yr climate cycle in the western Mediterranean over the last 20 kyr

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High resolution analyses of marine sediments usually involve a constant spatial sampling interval. However, sampling usually results uneven and becomes irregular when the spatial scale is transformed to the time scale. As the Lomb-Scargle method of spectral analysis, which has been extended to perform cross-spectral analysis, is a very appropriate method for the analysis of uneven time series, it has been utilized to investigate periodicities in a selected sediment core from the westernmost Mediterranean Sea over the last 20 kyr. Previous spectral analysis on this time interval revealed four significant cycles that were interpreted as related to diverse climate forcing mechanisms at regional and global scale. Here we present further cross-spectrum analysis on time series from selected paleoenvironmental proxies that evidence leads or lags in the 1,400-1,500 yr climate cycle. This periodicity, known as Bond cycles, is recognized in terrigenous, redox and productivity proxies, sea surface temperature (SST) and salinity indicators, although none in the phase spectrum. Redox and paleoproductivity proxies responded in intermedium phase with medium (>90%) to high confidence level (<95%) leaded by 347-436 yr with respect to the terrigenous proxy represented by K/Al ratio. Furthermore, SST and salinity proxies were in the non-phase spectrum with very high confidence level (>95%) with the K/Al ratio, and in the intermedium phase with U/Th ratio by 430 yr lead, and non-phase with V/Al ratio, as redox proxies, respectively.



P-046

## Exploring the links between Reef growth, regional paleocyanography and global global climate throughout the Mid-Pleistocene Transition.

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*The history of reef growth in New Caledonia area is derived from deep sea sediment records using a novel multidisciplinary approach which enables to extend our knowledge beyond that traditionally derived from borehole data. Borehole data provides limited spatial information on reef growth and is affected by periods of erosion. Periods of rapid reef growth during sea level rise are associated with increased release of CO<sub>2</sub> to the atmosphere and potentially provide feedbacks between global climate and carbonate production via the global carbon cycle. Previous work showed that Pleistocene reef history, investigated via reef boreholes, experienced a large global expansion of reefs between 400ka and 800ka, thus a causal link was proposed between the unusually warm interglacial, MIS11, and reef expansion.*

*We identified coral rich shelf-derived material, deposited within turbidite layers, in a deep-sea sediment core collected offshore New Caledonia Barrier Reef. The 1.3Ma chronology is based on *G. ruber* stable isotope profile. Sediments are predominantly composed of carbonate ooze, into which the sandy turbidite layers are deposited. These layers interrupt, but do not disturb the background sedimentation and contain well preserved coral fragments. Additional constraint on the abundance of coral rich deposits is derived from XRF measurements for [Sr], a proxy for aragonite. Our results indicate an interval of reduced reef growth between 0.9-0.4Ma. Comparisons with global records seem to show that there could be a link between changes in sea level and changes in reef production during the Mid-Pleistocene Transition.*



P-047

## Planktic foraminiferal stable-isotopes across the EECO: investigating the coupling between temperature and the exogenic carbon pool (ODP Site 1263, Walvis Ridge)

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*The Late Paleocene - Early Eocene warming trend is characterized by a gradual temperature rise of 5-6°C resulting in the Early Eocene Climatic Optimum "EECO". This warming trend was punctuated by several "hyperthermals", geologically brief (<200kyr) episodes of extreme warmth. Recently, a new, ~4.7 million year long, high-resolution benthic foraminiferal stable isotope record of ODP Site 1263 has been presented, which confirms the presence of hyperthermals during and at the termination of the EECO as was previously found for ODP Site 1258. Also, the record reveals a highly significant linear relationship between  $\delta^{18}O$  and  $\delta^{13}C$  for these events, similar as for their early Eocene counterparts. This indicates a strong coupling between global warming and the release of isotopically light carbon into the ocean-atmosphere system throughout the EECO. Whilst the coupling  $\delta^{18}O$  and  $\delta^{13}C$  remains stable on short-term time scales, this is not the case for the long-term trend. At ~52 Ma, when a rapid  $^{13}C$  enrichment in carbon data is not accompanied by changes in the oxygen record. Possibly, enhanced carbonate and organic carbon burial rates may be responsible for this shift due to a temporary reduced efficiency of the biological pump. To test this hypothesis, we will present our (preliminary) stable isotopic results of two planktic foraminiferal species derived from the same samples of ODP Site 1263, which portray changes in surface water (*Acarinia* ssp.) and thermocline waters (*Subbotina* ssp.).*



P-048

## High resolution geochemical and magnetic records from a new benchmark deep sea section across the Eocene-Oligocene transition

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*The Eocene-Oligocene Transition (EOT; ~34 Ma) represents a pivotal tipping point in the development of the Earth's modern climate system, triggering a climate state sufficiently cool to sustain extensive Antarctic ice sheets. Drift sediment sequences recovered at IODP Expedition 342 Site U1411 (SE Newfoundland Ridge, NW Atlantic) present a unique opportunity to study the EOT in unprecedented temporal resolution from a Northern Hemisphere perspective. Site U1411 benefits from high sedimentation rates, exceptional carbonate microfossil preservation and retention of a detailed record of the Earth's magnetic field behaviour. This enables development of a comprehensive stratigraphic framework for palaeoceanographic studies from a region where very little is known about EOT climate history. Here we present a magnetostratigraphy for Site U1411 spanning C13r/C15n up to the base of C12r. These magnetochrons provide key age constraints for correlating EOT geochemical records between sites and ocean basins and provide the framework to investigate the rate of environmental change. Complementary anhysteretic remanent magnetisation (ARM), magnetic susceptibility, x-ray fluorescence (XRF) and bulk isotope data reveal cyclic variability across this interval and highlight the utility of continuous magnetic measurements in reconstructing environmental variability in the North Atlantic at the onset of Antarctic glaciation.*



P-049

## **Astronomical tuning of the La Vedova section (Ancona, Italy) between 16.3 and 15 Ma. Implications for the origin of megabeds and the Middle Miocene Climatic Optimum.**

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*The Middle Miocene Climatic Optimum (MMCO) followed by the Middle Miocene Climate Transition (MMCT) represents a crucial period in Earth's climate evolution. To understand this episode and reconstruct its origin and the regional impact of the observed global changes, it is critical to develop high-resolution astronomical age models for climate sensitive regions. One of these areas undoubtedly is the Mediterranean, but so far no such an age model has been established for the interval of the MMCO. Here, we present an astronomical time scale for the younger part of the MMCO, between 16.3 and 15 Ma, from the Mediterranean. It is based on the litho-bio-magnetostratigraphic and geochemical records of the La Vedova section (Italy), which is characterized in its lower part by the occurrence of 7 conspicuous limestone beds, termed megabeds, alternating with marl intervals. Tuning to eccentricity seems robust: individual megabeds are related to minima of the ~100-kyr cycle and the whole megabed interval shows a relation with the 405-kyr cycle, but not with the 2.3 and 1 myr eccentricity cycles. The megabed interval is probably linked to a regional tectonic activity and to the likely associated Langhian transgression. Tuning to precession is less certain, as a consequence of the not clearly developed structure of the basic cycles and of the uncertainties in the phase relation, since the precessional cyclicity is expressed by intercalation of greenish gray layers, characterized by Ca/Al maxima and Rb/Al and Ti/Al minima.*



P-050

## Orbitally paced climatic variations of the North Atlantic during the Mid Eocene: Implications from a ~2 Myr benthic isotope record in the North Atlantic (IODP Exp. 342)

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*The middle Eocene marks the successive climatic transition from a greenhouse world during the early Eocene Climatic Optimum (EECO) into much cooler conditions culminating in the onset of Antarctic glaciation at the Eocene/Oligocene boundary. No high-resolution stable isotope records from benthic foraminifera yet exist for crucial parts of the so-called "Eocene Gap" as a result of a shallow calcium compensation depth (CCD), preventing the deposition of cyclic carbonate rich sediments during the mid-Eocene [Pälike et al., 2012]. IODP Expedition 342 drilled carbonate-rich sequences from sediment drifts offshore Newfoundland that cover the Eocene Gap with high sedimentation rates (> 3 cm/ kyr). We present an astronomically tuned ~2 Myr long stable carbon and oxygen isotope record of benthic foraminifera *nuttalides truempyi* spanning magnetochron C20r in unprecedented resolution (< 2 kyr), sufficient to resolve dominant Milankovic frequencies. Oxygen isotopes from U1410 range between -0.5‰ and 0.4‰ and show climatic variations on orbital time scale superimposed on a long term increase of ~0.1‰/Myr. Initial spectral analysis of carbon isotope records (~-0.3‰ to 0.5‰) reveals sensitive response of Atlantic Meridonal Overturning Circulation (AMOC) on Milankovic time scales in our time series.*



P-051

## A 45-kyr record of millennial terrestrial-marine climate variability from the Mozambique Channel

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*Marine sediments deposited off the Zambezi River provide a detailed archive of the climatic and environmental conditions prevailing in the ocean and on the adjacent southeast African continent. Here, we present high-resolution records of magnetic susceptibility (MS), XRF core scanning, lithogenic grain-size distributions and neodymium isotope signatures of the lithogenic clay fraction from a coring site (64PE304-80, ~1330 m water depth) located at a key position to reconstruct atmospheric and oceanographic changes. The chronology of this sediment core is well-constrained by AMS radiocarbon ages and spans the last ~45 kyrs. Lithogenic proxy records (i.e. neodymium isotope signatures, grain-size distribution and subsequent end-member modeling) indicate an enhanced accumulation of fine-grained sediments originating from the Zambezi catchment during precession-induced maxima in southern hemisphere solar insolation onto which northern hemisphere cold events are superimposed at millennial time scales. These intervals of fine grained sediment deposition probably reflect increased discharge from Zambezi catchment due to a more southern position of the Intertropical Convergence Zone (ITCZ) and Congo Air Boundary (CAB). Variations in marine versus terrestrial sediment accumulation, derived from XRF core scanning are not coherent with changes in lithogenic composition. This offset indicates asynchronous forcing of terrestrial and marine climate signals, in particular during Heinrich Stadial 1 and the Younger Dryas. The time lag may be related to changes in sediment transport by the net southward, eddy-induced flow through the Mozambique Channel.*



P-052

## Carbon isotope signature and precession-scale chronology of the Paleocene-Eocene Thermal Maximum in a terrestrial setting

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*The Bighorn Basin in Wyoming provides expanded terrestrial sections that span the PETM and lack the carbonate dissolution hampering many marine records. Here we provide carbon isotope records at unprecedented resolution for the Polecat Bench and Head of Big Sand Coulee sections, parallel sites in the northern Bighorn Basin. Cyclostratigraphic analyses of these fluvial sediment records using descriptive sedimentology and proxy records allow subdivision into intervals dominated by avulsion deposits and intervals dominated by overbank deposits. These sedimentary sequences alternate in a regular fashion, related to climatic precession. Correlation of the circa 7-km-spaced sections shows that the avulsion-overbank cycles are laterally consistent. The presence of longer-period alternations, related to modulation by the 100-kyr eccentricity cycle, corroborates the precession influence on the sediments. The cyclicity is then used to develop a floating precession-scale age model for the PETM carbon isotope excursion (CIE). We find a CIE body encompassing about 100 kyrs, in line with marine cyclostratigraphic age models. The CIE initial recovery is a 2 to 3 per mille step and the recovery lasts circa 40 kyrs.*



P-053

## Sediment record of paleoenvironment of the central mud of the South Yellow Sea and its response to the East Asian Monsoon during Holocene

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*The Yellow Sea Warm Current (YSWC) plays a key role in the formation of the central circulation of the South Yellow Sea (SYS), and the evolution of marine sediment environment; however, previous studies lacked continuous high-resolution paleoenvironment indicators: mostly limited to discussions on its formation time. It is very important to mention that dating has been considered a bottleneck due to lack of foraminifera in the is tested. Using AMS <sup>14</sup>C dating, Grain size and geochemical data, paleoceanography records since 7.3 ka B.P. are known. We find out that:(1)The East Asian Monsoon (EAM) presents cycles of 1471 a, 420~490 a, 65a, 40a, 28 a, 21 a, which correspond to the solar activity cycles. During the period between 10~3ka, thermohaline circulation in the high latitude controls the paleoclimate change of the East Asia. During the period between 3~0 ka, ENSO mainly impacts the EAM evolution.(2)During the period between 6.8~2.8ka, SST was mainly affected by global climate change, while the YSWC is the controlling factor of SST during the period between 2.8~0ka.*

*(3)Productivity evolutionary record of YSO1 is controlled by ENSO on millennial time scales, while the productivity improves owing to the strengthened EAWM on short time scales. Paleoproductivity is consistent with the modern strengthened ENSO since 3ka, as well as with SST change of the SYS.*



P-054

## **New Eocene benthic stable isotope record in the Pacific: completing a 22 Ma single site high-resolution Paleogene section from Shatsky Rise**

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*The Early to Middle Eocene climate yields a number of transient global warming events (hyperthermals). The common finger print of hyperthermals is a paired negative excursion in  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  of carbonate sediments coinciding with a clay rich layer indicating carbonate dissolution. Up to 30 hyperthermals have been proposed to be present in Atlantic Ocean pelagic sediments. Some hyperthermals in the Pacific realm have been recorded in bulk stable isotope data from the Early Eocene in New Zealand, and deep sea cores from Sites 577, 1215 and Leg 198. Due to the lack of benthic foraminiferal  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  records for both the Atlantic and Pacific the overall extend of hyperthermal layers in the Early to Middle Eocene is unknown.*

*Here we present a new 12 million year high-resolution benthic stable isotope record (56 to 44 Ma) for ODP Site 1209 applying benthic foraminifera *Nuttallides truempyi* to identify hyperthermal layers and document their magnitude. This new benthic isotope record in addition extends an existing record for the same site comprising altogether a now unique 22 million years, single site, benthic isotope section at 5 kyr resolution from 66 to 44 Ma. Numerous paired carbon and oxygen isotope excursions and clay layers are found in the Early to Middle Eocene corresponding in timing and magnitude to most, but not all, hyperthermal events identified elsewhere. This new record from the equatorial Pacific reveals the true global extend of hyperthermal events as well as the significance of the involved carbon cycle perturbation.*



P-055

## Mid-Pliocene foraminiferal isotope stratigraphy of Eastern Equatorial Atlantic ODP Site 959

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*Global temperatures are projected to rise by 2-3°C relative to the pre-industrial era by the end of this century, assuming unabated CO<sub>2</sub> emissions. Such high global temperatures and reduced meridional temperature gradients during the mid-Pliocene Warm Period (mPWP, 3.29-2.97Ma) are typically attributed to a higher CO<sub>2</sub> concentration, reduced ice and cloud albedo effects and/or enhanced polar heat transport. Outstanding issues in solving this issue relate to zonal sea surface temperature (SST) gradients and variability, particularly in tropical regions.*

*Recent work and vigorous discussion has focused on zonal SST gradients and water column structure in the Pacific Ocean. We assess these critical factors in the Atlantic Ocean and generate high resolution proxy data at the Eastern equatorial Atlantic Ocean Drilling Program Site 959 (2100 m depth, 2 °N Pliocene paleolatitude). Here, we present preliminary benthic foraminiferal  $\delta^{18}O$  data spanning the interval between 3.6 and 2.6 Ma, providing the basis for a high resolution (precession scale) age model, with confident correlation to the stacked global benthic  $\delta^{18}O$  of Lisiecki and Raymo (2005, LR04). This will enable quantitative reconstructions of zonal and meridional SST gradients across the mPWP.*



P-056

## Orbital-scale variations in atmospheric CO<sub>2</sub> during the Paleocene and Eocene

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*Multi-million-year proxy records ( $\delta^{13}\text{C}$ ,  $\delta^{18}\text{O}$ , %CaCO<sub>3</sub>, Fe, etc.) show prominent variations on orbital time scale during the Paleocene and Eocene. The cycles have been identified at various sites across the globe and preferentially concentrate spectral power at eccentricity and precessional frequencies. It is almost certain that these cycles are an expression of changes in global climate and carbon cycling paced by orbital variations. However, little is currently known about (1) the driving mechanism linking orbital forcing to changes in climate and carbon cycling and (2) the amplitude of atmospheric CO<sub>2</sub> variations associated with these cycles. We have used simple and complex carbon cycle models to explore the basic effect of different orbital forcing schemes and noise on the carbon cycle by forcing different carbon cycle parameters. For direct insolation forcing (opposed to eccentricity – tilt - precession), one major challenge is understanding how the system transfers spectral power from high to low frequencies. We will discuss feasible solutions to this problem, including insolation transformations analogous to electronic AC-DC conversion (DC'ing). Our results show that high-latitude mechanisms are unlikely drivers of orbitally paced changes in the Paleocene-Eocene Earth system. Based on a synthesis of modeling and proxy data analysis, we present the first estimates of orbital-scale variations in atmospheric CO<sub>2</sub> during the Paleocene and Eocene.*



P-057

## A synthesis of deglacial deep-sea radiocarbon records and a test of their overall consistency with modern ocean circulation

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*Radiocarbon measurements on benthic foraminifera and deep-sea corals have been used to draw inferences about the rates and pathways of deep ocean ventilation during the last deglaciation. In particular, the past decade has witnessed a dramatic increase in the number of deep-sea radiocarbon records and a substantial debate surrounding their interpretation. Here we present a synthesis of (un)published deep-sea radiocarbon data collected from all major oceanic basins. Our compilation includes ~1000 deepwater age estimates, computed from the same calibration to IntCal13. As a preliminary analysis of these data, we develop a simple test of the null hypothesis ( $H_0$ ) that the deepwater age estimates do not require changes in ocean circulation during the last deglaciation, given the uncertainties in the basin-scale representativeness of site-specific data. The test relies on surface water  $\Delta^{14}C$  values obtained from a least-squares fit of a 16-box model characterized by time-invariant (modern) volume transports to the deepwater  $\Delta^{14}C$  records. We find that the fit requires some of the surface water  $\Delta^{14}C$  values to be either above the contemporaneous atmospheric  $\Delta^{14}C$  value or below a value that corresponds to infinite calendar age. In other words, the deep-sea radiocarbon data combined with modern volume transports lead to unrealistic surface water radiocarbon concentrations at some discrete times during the last deglaciation, suggesting that  $H_0$  should be rejected. In our presentation, we will discuss the robustness of this result against the assumptions in our analysis as well as its paleocyanographic implications.*



P-058

## Paleolatitude.org: a paleolatitude calculator for paleoclimate studies

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*Realistic appraisal of paleoclimatic information from a particular location requires accurate knowledge of its paleolatitude relative to the Earth's spin-axis. This can be reconstructed from tectonic plate reconstructions that restore relative plate motions and reconstruct all plates relative to the spin axis using a paleomagnetic reference frame. The necessity of using a paleomagnetic reference frame for climate studies rather than a mantle reference frame appears underappreciated. Here, we briefly summarize the theory of plate tectonic reconstructions and their reference frames tailored towards applications of paleoclimate reconstruction, and show that using a mantle reference frame, which defines plate positions relative to the mantle, instead of a paleomagnetic reference frame may introduce errors in paleolatitude of more than 15° (>1500 km). This is because mantle reference frames cannot constrain, or are specifically corrected for the effects of true polar wander. We used the latest, state-of-the-art plate reconstructions to build a global plate circuit, and developed an online, user-friendly paleolatitude calculator for the last 200 million years by placing this plate circuit in three widely used global apparent polar wander paths. As a novelty, this calculator adds error bars to paleolatitude estimates that can be incorporated in climate modeling. The calculator is available at [www.paleolatitude.org](http://www.paleolatitude.org). We illustrate the use of the paleolatitude calculator by showing how an apparent wide spread in Eocene sea surface temperatures of southern high latitudes may be partly explained by a much wider paleolatitudinal distribution of sites than previously assumed.*