PAGES Morillo de Tou 2017

3rd Young Scientists Meeting

Global Challenges for our Common Future:
a paleoscience perspective

ABSTRACT BOOK

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The photos included in this Abstract Book show different landscapes of Sobrarbe, the historic county that in the 11th century was incorporated to the kingdom of Aragón. Morillo de Tou belongs today to the municipality of Aínsa, capital of Sobrarbe since the Middle Ages. © R. Domingo.

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POSTERS

YSM 1 - Climate system dynamics

Speleothem δ18O record of multidecadal Atlantic oscillations during the last millennium in Morocco

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The climate processes in Morocco are poorly understood, making the investigation of paleoclimate changes during the last millennium highly requested. Here, we present the first well-dated high-resolution stable oxygen isotope δ18O speleothem record from southwestern Morocco, covering the last 1200 years. Our record reveals substantial decadal to multidecadal fluctuations between dry and humid periods, consistent with regional paleorecords, with prevailing dry conditions during the MCA, wetter conditions during the LIA, and a trend towards dry conditions during the current warm period. Statistical analyses indicate that the climate in Morocco remained under the combined influence of both the AMO and NAO over the last millennium. The generally warmer MCA and colder LIA at longer multidecadal timescales probably influenced

the regional climate in North Africa through the influence on Sahara Low, which weakened and strengthened the mean moisture inflow from the Atlantic Ocean during the MCA and LIA respectively.

Reconstructing Holocene hydrographic variability in the Northeast Atlantic using bivalves

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The bivalves Arctica islandica and Glycymeris glycymeris are highly resolved archives of past marine climate in the North Atlantic. The annual growth patterns of the shell reflect the environment the animals live in and by cross-matching these growth patterns it is possible to construct multi-centennial, replicated, and annually resolved chronologies that form a temporal template for isotope sampling. The aim of this study is to assess differences through time in marine climate and growth rates in isolated A. islandica and G. glycymeris populations in the northeast Atlantic Ocean. In May 2014 and April 2016, we collected dead valves and live specimens of both species from St Kilda, Outer Hebrides, Scotland. This area is of particular interest as it is close to the Scottish shelf margin, has negligible freshwater input and is thought to represent open-ocean North Atlantic signals well. We here compare inter-annual and seasonal growth in modern specimens with growth in two floating chronologies, each spanning >200 years, built from dead-collected shells. All the shells in the floating chronologies were found to have radiocarbon ages between 3700-3300 cal yr BP. The radiocarbon ages confirm our findings by grouping the shells into two distinct age bands consistent with our two floating chronologies. We present annual and sub-annual δ18O data of these floating chronologies as well as of modern specimens from St Kilda to compare changes in mean state and seasonality between the present and the fourth millennium BP. Sub-annual δ18O data from the floating chronologies and from the modern specimens show a strong seasonal signal and multi-year trends. We calibrate the δ18O results from the modern specimens with instrumental data, which enables us (assuming that there has been no change in δ18Owater) to compare mean and seasonal seawater temperatures between the present day and the fourth millennium BP.

Reconstructing regional sea-level changes in eastern Canada using salt-marsh testate amoebae

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Salt-marsh sediments and coastal deposits are routinely used to reconstruct relative sea-level (RSL) changes over the past few millennia at decadal and decimetre scale resolutions. Recently, progress has been made on the development of salt-marsh testate amoebae as a widely applicable and precise sea-level indicator. This contribution demonstrates the cosmopolitan vertical zonation of salt-marsh testate amoebae across the North Atlantic and presents results from the development of an applied regional training set of surface assemblage data. Recent and original late Holocene RSL reconstructions have been produced from eastern Canada using salt-marsh testate amoebae alongside foraminifera and other sea-level indicators. These reconstructions document differences in rates of RSL rise as a result of: i) local environmental dynamics; ii) isostatic uplift gradients and associated geophysical mechanisms; iii) regional processes governing ocean volume changes (e.g., ice-sheet dynamics and thermal expansion), and iv) drivers forcing ocean mass redistribution (e.g., ocean-atmosphere circulation patterns). The records show accelerations in the rates of RSL rise towards the end of the 19th century and during the early 20th century. Similar signals have been recorded from palaeo-evidence at several locations across the globe. These inflexions coincide with the increase in global temperature seen since the onset of industrialisation and with a downturn in the strength of the Atlantic Meridional Overturning Circulation. Improving multi-

proxy reconstructions, their chronologies, and their spatial coverage will be necessary for teasing apart the different mechanisms that drive RSL changes at local to regional scales. Mechanisms such as land-based ice-melt and ocean circulation changes currently contribute to rapid RSL rise during the 21st century but are yet to be accurately and precisely constrained for our recent past.

Climate evolution across the Mid-Brunhes Transition

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The Mid-Brunhes Transition (~430 ka; MBT) has been described as an increase in the glacial-interglacial climate cycles of the past 800,000 years. Temperature records from ice cores indicate that prior to 430 ka the interglacials were in fact cooler than those after the MBT. Additional records of benthic oxygen isotopes suggest that the interglacials from 430-800 ka experienced higher ice volumes relative to the younger interglacials. Yet to be answered though is whether the MBT was a global phenomenon or regional. Here we characterize the climate system across the MBT through geostatistical analyses of multiple climate proxies including sea-surface temperatures, benthic carbon isotopes, and dust accumulation. Our results demonstrate that the MBT was in fact a global event with a significant increase in climate variance. Furthermore, our analyses document a number of changes in other components of the climate system that began as early as MIS 14 and that may suggest a more complex sequence of events was involved in the MBT. In particular, we note strong Asian summer monsoons during MIS 14, a weak glacial, which would have been conducive to a build-up of Northern Hemisphere land biomass. A continued strong Asian summer monsoon during MIS 13 associated with greater precipitation would have further sequestered land biomass and provided a reservoir for light carbon, resulting in the oceans becoming unusually enriched in ∂13C. MIS 12 was associated with the return of large ice sheets, collapse of the Asian summer monsoon, the first increase in amplitude of Southern Hemisphere dust, and a drop in the latitudinal gradient of Atlantic ∂13C suggesting a reorganization of the water masses in the basin. Therefore we suggest a sequence of events leading up to the MBT starting at MIS 14 may suggest a more complex transition rather than a singular event 430 ka.

Shift in the glacial interglacial methane budget from dual isotope records

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Atmospheric methane records as reconstructed from polar ice cores represent a globally integrated view on processes predominantly taking place in the terrestrial biogeosphere. In this study we present dual stable isotope constraints on the natural methane sources derived from Antarctic ice cores which help to deepen our understanding. For the current and two older interglacials and their antecedent glacial maxima we can show, that tropical wetlands and seasonally inundated floodplains are most likely the dominating sources of atmospheric methane, steered by temperature and humidity as modulated by insolation, (local) sea level and monsoon intensity. The latter is also revealed on the basis of substantial δ13CH4 signals in the course of interglacials, accompanied by rather constant δD(CH4). Based on our new δD(CH4) constraint, geologic emissions of methane may play a steady but minor role, and the glacial budget is certainly not dominated by these sources. Superimposed on the glacial/interglacial variations a marked difference in both isotope records with systematically higher values during the last 25,000 years compared to older time periods is evident. This shift cannot be explained with climatic changes. Rather we invoke a change in fire regimes possibly due to accumulation of fuel and biome changes related to the late Pleistocene megafauna extinction which took place in the course of the last glacial.

The deglacial dynamics of the North American Monsoon in leaf wax isotopes and model experiments

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In many regions of the US Southwest and western Mexico, the North American Monsoon (NAM) provides up to 70% of annual rainfall. However, the past variability of the NAM is not fully understood, hindering our ability to narrow prognoses of its behavior under future warming.In this study, we seek to understand the mechanisms governing the deglacial evolution of the NAM. We present a record of leaf wax stable isotopes (e.g. dD of n-acids) that shows evidence of a suppressed monsoon and increased winter rainfall during the Last Glacial Maximum (LGM). We also use experiments with the model CESM1.2 to show that during the LGM, continental ice sheets created westerly wind anomalies that brought cold dry air into the NAM region, suppressing summertime convection. Our work provides a novel explanation for the dynamics of NAM suppression during glacial periods, improves the predictability of this circulation, and advances our understanding of monsoon systems.

The evolution of deep water circulation in the subpolar North Atlantic during the last glacial termination

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Authigenic neodymium (Nd) isotopes have become a valuable proxy for the reconstruction of past ocean water mass provenance. For an accurate interpretation of Nd isotope palaeo records, however, a precise knowledge of the Nd isotope signatures of possibly prevailing water masses is imperative. While there is evidence that the Nd isotope composition of North Atlantic Deep Water and its glacial pendant remained constant during the last glacial cycles [1], there is also data that conflicts with such constancy in deeper waters [2]. The subpolar North Atlantic is both the source region of North Atlantic Deep Waters as well as a very dynamic region that reacts sensitively to climatic changes like ice cover and surface temperatures. Furthermore, it is a region with vastly variable input in terms of Nd isotope composition. We reconstructed the deep water Nd isotope composition from several sites across the deep subpolar North Atlantic during the last transition from glacial to warm climate. While these reconstructions are complicated by variable inputs of easily weathered material from the continents, we are confident that they mainly react to changes in deep ocean circulation. They show that water exchange between the deep eastern and western basins was limited during the last glacial maximum, probably due to the weakening of the overflow waters from the North-East. During the early Holocene, a vigorous exchange between the two basins was established, evident through a homogenised Nd isotope signature across East and West. However, it further changes towards more radiogenic isotope signatures in both basins during the later Holocene. This continued change could indicate a strengthening of overflows exporting more radiogenic Nd from Iceland and would present a possible source for variations in the Nd isotope signature of North Atlantic Deep Water.

[1] Foster et al. (2007), Geology
[2] Böhm et al. (2015), Nature

Characterizing spatial and temporal scales of drought in the CESM and paleoclimate reconstructions

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This study analyzes the impact of stochastic atmospheric variability, relative to exogenous (solar, volcanic, orbital) and boundary (sea surface temperature—SST) forcings on the spatial and temporal scales of drought over the Northern Hemisphere. To do so, we employ a suite of model simulations from the Community Earth System Model called the Last Millennium Ensemble (LME). The LME includes 8 millennial-length exogenously

forced simulations, ideally suited to isolate the exogenously forced components of hydroclimate variability. Additionally, the LME includes individual experiments run with greenhouse gas, solar, volcanic, land use and orbital forcing to assess the specific impacts of the different exogenous forcings. An associated, 1000-year control simulation will be used to assess the range of internal hydroclimate variability and a new ensemble of simulations with the same configuration as the LME but with constant climatological SST boundary conditions will be used to assess the impact of stochastic atmospheric variability. This study builds off of previous research on the temporal scales of drought over individual regions by using a novel machine learning technique based on Markov Random Field methods that identifies drought in three-dimensional space-time. The joint space-time character of this technique allows, for the first time, both the temporal and spatial scales of drought to be analyzed over the full Northern Hemisphere. By comparing results from the model simulations to tree-ring based reconstructions of hydroclimate variability, the following questions are addressed: Can atmospheric variability explain the persistence, severity, and spatial features of drought in the reconstructions, or must the SST boundary forcing be invoked? If so, is internal variability sufficient or must some or all exogenous forcings be invoked? The answers to these questions provide critical guidance for paleoclimate reconstructions using hydroclimate proxies and for our understanding of real-world and simulated drought mechanisms on a range of timescales.

Age and inferred paleoclimate from Pleistocene-aged deposits in the Hudson Bay Lowlands, Canada

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Earth System Models, which are used to simulate past climates and project future conditions, require an accurate understanding of the dynamics of Pleistocene ice sheets. While we have a relatively good understanding of the most recent deglaciation, large knowledge gaps exist for periods prior to the Last Glacial Maximum (LGM), in particular the dynamics of the Laurentide Ice Sheet (LIS). The paleo-history of the Hudson Bay Lowlands (HBL), an extensive peatland spanning >370,000 km2 in central Canada, may be able to resolve this issue. Since the HBL lies near the center of many Pleistocene ice sheets, non-glacial deposits signal large-scale deglaciation over North America. Various non-glacial records (marine, fluvial, organic, lacustrine) have been found in this region, all of which are overlain by tills. However these records are highly fragmented and disparate, making the glacial history of this region a topic of ongoing research. Our review of existing (n=88) and new (n=39) age determinations from the non-glacial interval of many of these sites suggests an ice-free interval during Marine Isotope Stage 3 (ca. 57,000 to ca. 29,000 yr BP; Dalton et al. 2016, QSR). Glacial modelling suggests that the LIS may have been close to its maximum extent during MIS 3, therefore, these data suggest a significantly different configuration of the ice sheet over North American than previously believed. Efforts to improve these age determinations are underway. Non-glacial records from the HBL also offer rare insights into Pleistocene paleoclimate. For example, the Ridge Site, provisionally dated to MIS 3, contains a pollen and macrofossil record suggestive of peatlands and a climate slightly cooler/drier than today (Dalton et al. 201x, Boreas, in review). Thus, these records also enable estimates of pre-LGM peatland extent and carbon pools, and new insights into the global carbon cycle during the Pleistocene.

Spatio-temporal variability of the SPCZ fresh pool eastern front from coral-derived SSS data

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The South Pacific Convergence Zone (SPCZ) is a major atmospheric feature of the southern hemisphere. It is a low atmospheric

convergence band associated with intense precipitations. Its position and intensity responds to global changes but also modulates regional weather patterns. Interannual to long-term SPCZ modifications result in extreme events such as severe droughts or flooding with profound socio-economic consequences. The SPCZ oceanic counterpart is a large body of fresh water (SSS<34.5 pss) extending southeast from the Maritime Continent to the dateline. This freshpool is separated from the high-salinity waters of the South Pacific gyre to the west by a steep salinity front.

Various studies have shown a freshening of the freshpool and its south-eastward expansion since the 1970s, modulated by interannual to interdecadal variability (Cravatte et al., 2009). The scarcity of traditional SSS measurements limits our ability to describe accurately this variability. This study validates the use of coral d18O as a proxy for the reconstruction of SSS over the last 200 years. Derived SSS is validated against insitu data at 3 different locations along the SSS front (Fiji, Tonga and Rarotonga Islands). This new dataset enables us to investigate the spatio-temporal variations of the SSS front prior to the instrumental data.

Two robust modes of variability are present in the reconstructed SSS datasets: interannual variability and a secular trend. The reconstructed SSS variability follows El Niño Southern Oscillation index. The three sites present secular trends toward fresher conditions, but do not present similar variability, neither in timing nor strength over their total length. Furthermore, the role of atmospheric freshwater fluxes on SSS variability is evaluated by comparing reconstructed SSS to available historical rain gauge data. Results highlight the role of both atmospheric freshwater fluxes and ocean dynamics on SSS variability.

The inter-polar methane difference from the WAIS Divide and GISP2 ice-cores during Heinrich Stadials

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Ice core records of atmospheric methane show that on orbital and millennial timescales methane closely follows changes in Greenland temperature, presumably driven by variations in tropical precipitation / hydrology. Over glacial-interglacial cycles methane mole fractions can range from 350ppb up to 750ppb. Over the last 110,000 years, warm events referred to as Greenland Interstadials (GI), noted in Greenland ice core δ18O records and other global climate archives, are characterized by a coeval rise in atmospheric methane. At the onset of these events methane rises by 50 to 300ppb from Greenland Stadial (GS) concentrations. In addition to the GI/GS methane variations, there are distinct, though smaller, increases in methane during Heinrich Stadials (HS) 1, 2, 4 and 5 (Rhodes, Brook et al. 2015). These HS features in the methane record are unique as there is no coeval change in Greenland water isotopes.

Using the Inter-Polar Difference (IPD) of methane mole fractions, we investigate these periods and test the hypothesis that the Inter-Tropical Convergence Zone (ITCZ), normally positioned north of the equator, shifted southward during Heinrich Stadials, causing an intensification of monsoons and tropical wetland methanogenesis in the southern hemisphere and drying in the northern hemisphere. We obtained a high-resolution, high-precision methane record from the WAIS Divide and GISP2 ice cores covering GS 10 through GI 8 and GI 13 through GI 11. Because methane is sufficiently well mixed in the atmosphere to allow synchronization of gas chronologies between Greenland and Antarctic ice cores, yet has a short enough lifetime to preserve an inter-hemispheric gradient, a change in the latitudinal distribution of sources can be inferred from the difference between these two records.

Coherent millennial-scale hydroclimate variability in southern Australasia during the Last Glacial Period

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Drivers of long-term climate variability in the Southern Hemisphere (SH) are not well understood. The instrumental record does not extend far enough to encompass the full range of possible climate variability in the SH, including changes that may occur in the future. The Last Glacial Period (LGP; 30,000-10,000 yr. BP) was characterised by large, rapid climate fluctuations beyond what is preserved in the instrumental record, and in many cases without a clear external forcing. The LGP is therefore an ideal period in which to investigate the earth system response to external forcing and internal variability. LGP climate change in the high latitudes of the Northern and Southern hemispheres is well constrained, however LGP climate change on the continents of the SH mid-latitudes is poorly understood. Australasian climate proxy records are particularly sparse, and often confounded by local effects, coarse resolution, or poorly resolved chronologies. Coherent signals are consequently lacking in Australasian climate proxy datasets.

Here we present a new well-dated, high-resolution record of LGP hydroclimate variability inferred from the sediments of Lake Surprise in south-eastern Australia. Hydrological changes are interpreted from δ13C analysis of organic matter, and XRF-derived dust concentration. Both tracers indicate abrupt changes coeval with other sites across southern Australasia. We use a Monte Carlo Empirical Orthogonal Function approach to assess the shared response of these sites to internal and external forcings, and observe coherent millennial-scale variability in precipitation in these and several other Australasian sites. The MCEOF also identifies a ca. 2500 year oscillation that is not clearly aligned with Heinrich Events or Dansgaard-Oeschger cycles. The combined proxy evidence suggests that Antarctic temperature and Southern Ocean sea surface temperature are strongly correlated with precipitation at the south-east Australasian sites during the LGP, providing an important constraint on climate model simulations for the LGP.

ENSO flavours- Spatial dynamics of ENSO during the pre- industrial period

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El Niño-Southern Oscillation (ENSO) is the largest driver of interannual variability in the global climate system. Recent studies carry out major changes in frequency and intensity of canonical ENSO events. Under greenhouse warming scenarios an increase in frequency of extreme El Nino and La Nina events is being projected. Recent work has identified different 'flavours' of ENSO, for example, classical cold-tongue ENSO events and non-conventional El Niño definitions like the Central Pacific, Modoki and warm pool El Niño events.

A central question is to understand the dynamical aspects of the variety of ENSO events in a changing climate prior to the instrumental period. Different ENSO dynamics arise out of complex ocean-atmosphere interactions on various space and time-scales.

We present the first sub-seasonally resolved reconstruction of El Niño Southern Oscillation (ENSO) events based on a multi-century seasonally resolved network of tropical coral records.

The comparison with instrumental observations and existing ENSO reconstructions exhibits high agreement on interannual timescales but importantly highlights the merit of seasonally resolved proxies in studying ENSO dynamics.

The reconstructions are used to explore seasonal to multi-decadal time scale variability and trends in frequency, duration and propagation direction of ENSO events.

Differential response of Holocene climate variability observed from lake records along an elevational gradient in the intermediate latitudes of the Southern Hemisphere

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We present a temporal analysis of high-resolution geochemical data series obtained from Holocene sediment cores recovered from two lakes in central Chile (Laguna del Maule [LdM: 36ºS, 2200 m] located in an active volcanic field the Andes, and Laguna Vichuquén [VIC: 34°S, 72º 05′ W, 4 m] on the coast) to study the existence of cycles associated with climatic forcing. Temporal dynamics were established using a spectral analysis (Morlet wavelet power spectrum or MWPS and Lomb-Scargle Fourier Transform or LSFT) and break points methods for quantifying major climate transitions present in the geochemical proxies. Both sequences reveal high periodicity. The MWPS analysis for the LdM sequence shows two periods of minimum variability between ~13-9 ka and 7-5 ka, which occurred during lower lake levels. The wavelet and LSFT analysis show significant peaks at ca. 5000, 200 (De Vries/Suess oscillation), 80 (Gleissberg cycle), and 60-yrs cycles for LdM and at 1500, 650, 300, 13, 10.5 (11-yr Schwabe cycle), and 5.5-yrs (ENSO) cycles for VIC. During the mid-Holocene, the VIC record shows low-frequency cycles in productivity, clastic input and paleoredox indicators that appear to be driven by the Southern Westerlies (SW) variability at centennial scales. Both records are underlain by a period of minimum variability between ~7–4/3 ka that was coeval with aridity at the regional scale prior to 3-4 ka. Bioproductivity began to increase ~4-3 ka in both records as evidenced by the MWPS analysis, which could reflect the onset of modern ENSO dynamics. These cycles are related to the ENSO/PDO though changes in the dynamics of the SW and Hadley Cell circulation. Also, the dominance frequencies in the spectra with similar periodicities as solar activity suggest that this could have been a dominant forcing of paleoclimate during the Holocene in the Central Chile.

Reconstructing relative sea-level in Northern Greenland from marine bivalves

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The Greenland Ice Sheet (GIS) holds an ice-mass equivalent to about 6 meters of eustatic sea level equivalent. Understanding its melt dynamics and placing its vulnerability within the climatic context of the Holocene is essential in order to better constrain glacio-isostatic adjustment (GIA) models and predict future GIS contributions to global sea level. Commonly, model constraints for relative sea level variations consist of limiting ages obtained from marine shells exposed on land. A key uncertainty is the water depth of shell growth, which may vary over many 10′s of meters. Radiocarbon dates from bivalve samples collected on raised marine deposits during the Petermann15 Expedition (July 2015), in Hall Land, Washington Land of NW Greenland near Petermann Glacier, a major outlet of the Greenland Ice Sheet, and the Cape Baird region of Ellesmere Island constrain relative sea-level histories during the last deglacial period as well as during MIS3. Here we correct for shell depth habitats based on δ18O in each dated shells and in the modern water column, assuming that past vertical gradients in water column δ18O were roughly similar to today. We find this assumption breaks down during times of rapid relative sea level fall associated with regional ice loss, implying specific times of substantial meltwater input during glacial retreat. Both raw data and habitat-corrected data suggest a significant mismatch with previously employed GIA models, both in amplitude and rate of relative sea level change: Compared to the GIA model HUY3 we find that relative sea level during MIS 3 may have been several 10s of meters higher than predicted by the model. In addition the data suggest that the model not only

underestimates the rate of sea-level change during deglaciation but also misrepresents the timing when maximum ice-loads are reached. This study may therefore provide a new view of ice load history in Northern Greenland, and points towards the importance of including marine ice dynamics in models of ice retreat, and, perhaps, better constraints on regional variations of viscosity in GIA ice-models.

Early Pliocene vegetation and hydrology changes in western Ecuador

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During the early Pliocene, two major tectonic events triggered a profound reorganization of ocean and atmospheric circulation in the Eastern Equatorial Pacific (EEP), the Caribbean Sea, and on adjacent land masses: the progressive closure of the Central American Seaway (CAS) and the uplift of the northern Andes. These events presumably lead to a shift in the mean latitudinal position of the Intertropical Convergence Zone (ITCZ), which would have affected the continental climate. The direction of an early Pliocene ITCZ shift however is still debated, because numerical modelling results and paleoceanographic data indicate shifts in opposite directions. To resolve this contradiction, an independent hydrological record of the region is needed. A study site in the EEP was chosen to reconstruct the early Pliocene vegetation and climatic history of western Ecuador, due to its sensitivity to ITCZ shifts. For this, 49 pollen samples from marine sediment core ODP 1239A were analyzed. The presented pollen record comprises representatives from five vegetation types: lowland rainforest, lower montane forest, upper montane forest, páramo, and broad range taxa. The main finding is the persistence of a broad tropical rainforest coverage in the whole study area throughout the early Pliocene. From 4.7 to 4.44 Ma and around 4.2 Ma, the record reveals increasing humidity. This is reflected through increasing percentages of lowland rainforest and lower montane forest, a high spore content and high linear sedimentation rates. The development of the different vegetation types reveals stable, permanently humid conditions. This is in agreement with paleoceanographic data indicating a southward ITCZ shift in response to CAS closure. Increased orographic precipitation during this period resulting from the uplift of the Northern Andes intensified humid conditions. The exact timing of an early Pliocene ITCZ shift and the question whether it was a direct response to CAS closure or not remains unclear.

Robust evidence for forced changes in ENSO: from the mid-Holocene to the 21st century

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The El Niño-Southern Oscillation (ENSO) represents the largest source of year-to year variability; however, its sensitivity to external climate forcing, whether natural or anthropogenic, is difficult to assess with available records. High-resolution paleoclimate reconstructions of ENSO provide a comprehensive view of ENSO variability through the last centuries to millennia, particularly monthly-resolved coral δ18O records from the heart of the ENSO region, in the central tropical Pacific (Cobb et al., 2013). Here, we extend the paleo-ENSO record through the generation of 16 new fossil coral δ18O timeseries, averaging 15yrs each, for a total of 233 years of data that greatly augment the available paleo-ENSO archive. Combining this new dataset with published data, we quantify the differences in natural variations in ENSO from the mid-Holocene to present using a variety of different null hypotheses that includes multi-millennial simulations from both statistical and dynamical models of ENSO variability. We document a significant increase in recent

ENSO variance as compared to the last 7,000 years, implying a role for greenhouse gases in driving an intensification of ENSO. We also find a significant reduction in ENSO variance of roughly -20% from 3,000-5,000yr before present, relative to the preceding and subsequent intervals of data. The causes of the late mid-Holocene reduction in ENSO variance may be linked to the influence of fall and/or spring equatorial insolation forcing, which perturbs the seasonal cycle at the critical growth and decay phases of ENSO extremes, respectively. Our findings imply that ENSO is sensitive to external forcing, both natural and anthropogenic, although the precise mechanisms for such responses require further study. Our results imply that anthropogenic climate change has likely contributed to the recent record-breaking El Niño events, and that future ENSO variance is likely to remain strong under continued greenhouse forcing.

Medieval Aridity in the Central Tropical Pacific

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The spatial structure of last millennium hydroclimate history in the tropical Pacific requires continuous, high temporal resolution archives of past moisture balance across spatial gradients of precipitation. To date, only one 1300-year terrestrial record of hydroclimate is available for the central tropical Pacific, limiting the ability to test hypotheses regarding past patterns of hydroclimatic change. Here we present a new brackish lake sediment record from Kiritimati Island (1.9° N, 157.4° W) that provides a critical test of past Intertropical Convergence Zone migration for the central tropical Pacific. Geochemical and sedimentological data indicate centennial periods of fresher and more saline lake water during the last 2000 years. An episode of increased microbial mat development and gypsum precipitation defines 900 to 1250 CE, coincident with the Medieval Climate Anomaly (MCA), indicating a period of enhanced salinity and extended aridity. A shift from gypsum and microbial mats to carbonate sediment at the transition between the MCA and the Little Ice Age (LIA) supports the hypothesis of a southward shift in the ITCZ at this time and increased precipitation over Kiritimati. However, the LIA does not appear anomalously wet in Kiritimati relative to the 20th century, and microbial mats continued to grow at multidecadal intervals until 1700 AD. The periodicity of sub-mm scale laminations within the buried microbial mats is highly variable, and indicates mat-carbonate laminae are too frequent to be related to seasonal or ENSO periodicity. Such laminae are likely related to the organization of microbial communities and organomineralization along environmental microgradients in microbial mats rather than climate variability.

Long-term variation of clay mineral compositions in the Andaman Backarc Basin since the late Miocene

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Clay mineral studies in the Andaman Sea helped to understand the interaction between climate change and monsoon strength by revealing the erosional history of the Himalayan-Tibetan and Indo-Burman ranges during the late Quaternary. IODP Exp. 353 Site U1447 (10°47.4′ N, 93°00′ E), located at a water depth of 1391 m on a ridge ~45 km offshore the Little Andaman Island within the Andaman Backarc Basin, was drilled to penetrate 738 m beneath the sea floor. Chronostratigraphy of Hole U1447A was established by using shipboard biostratigraphic and paleomagnetic data, showing the late Miocene (~10.0 Ma) at the bottom of core. Seventy nine sediment samples were taken from 150 to 737 m CSF-A at Hole U1447A at ~8 m intervals for determining clay mineral compositions in order to probe the major controlling factors for their long-term variation patterns. At Site U1447, smectite (28~61%) and illite (20~40%) are the most dominant clay minerals while kaolinite (9~19%) and chlorite (5~15%) are subordinate. Variation pattern of clay mineral compositions exhibits three

prominent features: (1) mostly consistent variations of all clay minerals at 750~570 m (~10.0 to 7.5 Ma) interval, (2) gradual decrease of smectite and increase of illite and chlorite at 570~400 m (~7.5 to 4.5 Ma) interval, and (3) large fluctuation of all clay minerals at 400~150 m (4.5 to 1.1 Ma) interval. Much of the terrigenous sediments from the Himalayan-Tibetan and Indo-Burman ranges mainly through the Irrawaddy and Salween rivers and additionally through the Ganges-Brahmaputra rivers discharged into the Andaman Sea. Long-term variation patterns of clay mineral compositions in the Andaman Backarc Basin may be related to various factors such as provenance shift, climate changes, monsoon strength, and tectonic/volcanic activity.

Palynology discovers the plants response to climate changes during the last interglacial at Lake Ohrid (FYROM/Albania)

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The importance of Lake Ohrid (Albania / FYROM) as precious archive of climate change, biodiversity, volcanic ashes, and tectonic activity is noteworthy. The lake is considered the oldest continuously existing lake in Europe and is declared UNESCO World Heritage Site. The lake hosts over 210 endemic species that make it one of the largest water-reserves in the world.
Since 2013 the lake has been object of a multidisciplinary study that has involved about 50 scientists from 10 countries. 6 parallel cores, recovered thank to the ICDP (International Continental Scientific Drilling Program) support, have been collected from the depocenter of the lake. They reach the impressive length of 569 m and span at least the last 1.2 million years.
A portion of the sequence has already published (Sadori et al. 2016, Biogeosciences 13: 1423-1437). It covers the top 200 m (about the last 500,000 years) at a time resolution of about 1600 years. The record evidences the cyclic changes of at least five glacial/interglacial cycles and a general long trend from cooler and wetter to warmer and drier conditions.
In this frame, pollen analysis has been improved for sediments ascribed to the last interglacial complex (LIC) corresponding to marine isotope stage 5 (MIS5). Thanks to the detailed chronology (Francke et al., 2016 Biogeosciences 13, 1179-1196; Zanchetta et al., 2016, Biogeosciences 13, 2757-2768) and the increased time resolution analysis (roughly one sample every 400 years) this work is a valuable contribution to the LIC knowledge. Preliminary results show that mesophilous communities prevailed, during the interglacial Eemian and during the two interstadials, on montane ones and that Mediterranean vegetation was less spread than expected.

Stable Isotopes of Carbon Reveal a Complex Trajectory for CO2 Drawdown at Last Glacial Inception

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Roughly half of the interglacial-glacial drop in atmospheric CO2 occurred abruptly ~70 ka ago during the marine isotope stage 5/4 transition, suggesting significant and rapid shifts in the processes controlling carbon cycling on land and in the oceans. Although ice age/ interglacial carbon cycle dynamics have been the topic of a large body of modeling and empirical research, the exact mechanisms contributing to the glacial CO2 drawdown are not known. We use a high-resolution, high-precision record of the δ13C of atmospheric CO2 preserved in an Antarctic horizontal ice core to infer the timing and magnitude of changes in carbon cycle processes that occurred in association with global cooling and the expansion of ice sheets during the last glacial inception. The δ13C of CO2 traces carbon cycle dynamics because the stable isotopes of carbon fingerprint different processes of CO2 addition/ removal. Our measurements reveal 0.50 of depletion between ~71-70 ka followed

by 0.75 of enrichment from ~70-68 ka, suggesting a complex trajectory for the glacial CO2 drawdown with different processes dominating at different times during the transition. Qualitatively, our record is consistent with CO2 sequestration resulting from cooling sea surface temperatures and subsequent increases in the efficiency of the ocean biological pump. Experiments employing the University of Victoria Earth System Climate Model are underway to interpret the δ13C record quantitatively, the results of which are intended to constrain the likely CO2 sequestration pathway(s). The conclusions of this study contribute to a more complete, mechanistic understanding of the relationship between the carbon cycle and global climate.

Common Era climate reconstructions from the northeastern United States

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High-resolution paleoclimate records are essential for improving detection and attribution of internal and forced climate system responses. The densely populated northeastern United States is at high risk from increasing temperatures, changes in storm intensity and frequency, droughts and floods, and sea level rise. The region has limited annual or seasonal-scale proxy climate records beyond the instrumental record. Here we present a network of Atlantic white cedar tree-ring chronologies across the northeastern United States. Ring width variability reflects winter through summer temperatures at inland sites in the northernmost section of the species' range. Multivariate climate signals embedded in the full northeastern network are evaluated for their potential to provide reconstructions of both temperature and drought variability. We demonstrate skillful climate reconstructions for the last several centuries and the potential to use sub-fossil samples to extend these records over the entire Common Era. Our tree-ring network provides the long-term context at multidecadal and centennial time scales for the large-scale ocean-atmospheric processes that influence the climate of the region.

Late Holocene paleo-records of atmospheric dust deposition in eastern Canada.

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Atmospheric mineral dust plays an important role in the Earth's climate through parameters such as atmospheric radiation, cloud properties and biogeochemical cycles. However, the high spatial and temporal variability of mineral dust and a lack of terrestrial archives in certain regions limit our understanding of global dust-climate interactions. Ombrotrophic peatlands (bogs; atmospherically-fed only) have proven to be valuable archives of atmospheric dust deposition as their accumulation rate can provide high resolution paleo-climate reconstructions for the Holocene.
Dust deposited on two ombrotrophic peat bogs of the St. Lawrence Gulf and Estuary north shore was geochemically characterized using REE concentrations, Nd and Pb isotopes. Both cores display similar εNd values, which suggests either a common source or sources with similar signatures within the two regions. Combining Nd isotope data with REE patterns and particle size allowed for better insights into the source of deposited dust and the inference of past environmental and climatic conditions in both regions. REE elements, εNd and particle grain-size distribution suggest that, over the last 2000 years, the Baie bog received more local dust due to increased local storminess in response to regional hydroclimatic instability. The same phenomenon occurred in the IDH bog since 620 cal a BP, i.e. during the Little Ice Age, where hydroclimatic and paleoecological changes have been previously documented. While the dust reconstructions and regional climatic records agree relatively well, the discrepancies between paleodust records highlight the complex and variable structure of late Holocene changes in paleoclimate and more

particularly past dust deposition in eastern Canada.

High-res. flood history in lake sediments from SW Ecuador of the past two millennia: El Niño or not?

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ENSO is a top priority in current climate change research and globally relevant, not only for weather but also for ecosystems and society.
Rodbell et al. (1999) and Moy et al. (2002) related clastic layers in a sediment core from Lake Pallcacocha, SW Ecuador, with El Niño events. They argued that these events, which increase convection over the Pacific Ocean, lead to enhanced precipitation on the western side of the Andes (based on precipitation data from the station Guayaquil on the Pacific Ocean shore). They hypothesized that heavy precipitation events intensify river discharge and enhance watershed erosion, creating flood-event layers in Lake Pallcacocha's sediments.
However, Lake Pallcacocha lies on the eastern side of the highest Andean Ridge, and several authors showed that ENSO impacts areas on the eastern side of the Andes differently: El Niño events weaken (wet) easterly winds and strengthen (dry) westerly wind flows, ultimately leading to less precipitation. In contrast, La Niña conditions intensify easterly winds (SASM; wet) and weaken the dry westerly wind flows, which leads to increased precipitation on the eastern side of the Andes and would promote event layers in the sediments of Lake Pallcacocha.
The present study is based on non-destructive (uXRF, hyperspectral imaging) and destructive lake sediment core analysis from three different lakes (Pallcacocha, Llaviucu, Fondococha), all containing clastic layers. Is the flood history (frequency) consistent in these three lakes for the past ca. 2000 years? Can the newly available synoptic meteorological data and the new precipitation data from stations in the Cajas National Park be used to draw a conclusive picture about the atmospheric conditions producing flood layers? Do these layers really reflect variations in ENSO over the past two millennia? And if so, which events (El Niño or La Niña) caused these layers?
This study contributes to PAGES-2k-South America.

Climate and chemistry variability at the Pine Island Glacier ice divide, Antarctica

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The Mount Johns ice core (79º55'S; 94º23'W) was drilled near the Pine Island Glacier ice divide on the West Antarctic Ice Sheet during the 2008 2009 austral summer, to a depth of 92.26 m. The upper 45 m of the record covers approximately 125 years (1883-2008) showing marked seasonal variability. Trace element concentrations in 2,137 samples were determined using inductively coupled plasma mass spectrometry. In this study, we reconstruct mineral dust and sea salt aerosol transport and investigate the influence of climate variables on the elemental concentrations to the MJ site. The ice core record reflects changes in emissions as well as atmospheric circulation and transport processes. Our trajectory analysis shows distinct seasonality between summer and the others seasons, with strong westerly transport in the winter months and a secondary northeasterly transport in the summer. During summer months, the trajectories present slow-moving (short) and are more locally influenced than in others seasons. Finally, our reanalysis-element correlations suggest that marine derived trace element concentrations are strongly influenced by sea ice concentration and sea surface temperature anomalies. The results show that seasonal elemental concentration maxim in sea-salt elements correlate well with the sea ice concentration winter maxim in the West Amundsen and Ross Seas. Lastly, we observed an increased concentration of marine aerosols when sea surface temperature decreased.

Simulated sensitivity of the tropical climate to extratropical thermal forcing

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This study investigates the Intertropical Convergence Zone (ITCZ) response to an extratropical thermal forcing using an atmospheric general circulation model coupled to low (slab) and medium complexity ocean models. We focus on the relative roles of the atmosphere, the tropical sea and land surface temperatures (SST and LST) and the tropical ocean dynamics.
The imposed forcing consists of cooling in one hemisphere and warming in the other, poleward of 40° and with zero global average, and is intended to represent the asymmetric temperature changes associated with glacial-interglacial and millennial-scale climate variability.
We find that the ITCZ response to the extratropical forcing is not possible just trough purely atmospheric processes, but needs the involvement of either the tropical SST or the LST. In particular, the LST plays a mayor role in determining the ITCZ response over Africa and the Atlantic Ocean. The clear-sky longwave radiation effect is highlighted as the main physical mechanism behind this land-based extratropical to tropical teleconnection. Furthermore, our experiments indicate that the tropical ocean dynamics tends to oppose the incoming remote signal, generating weaker annual-mean signals than when only a slab ocean model is coupled in the tropics.

Discriminating the impacts of Heinrich and Dansgaard-Oeschger stadials over tropical South America

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Detailed knowledge about responses of tropical South American precipitation to Heinrich (H) and Dansgaard-Oeschger (DO) stadials allows more accurate insights into potential evolution of Amazon biodiversity under future climate. Sediment core GeoB16224-1 (ca. 7˚ N), raised from the continental slope off French Guiana in western equatorial Atlantic, documents the role of oceanic currents in transporting Amazonian Andes-sourced sediment during H and DO stadials from 13-41 ka. In combination with published high temporal resolution paleorecords across Central and South America between ca. 17˚ N and 4˚ S, we also differentiate the spatial features of tropical South American precipitation along with H and DO stadials, respectively. Our results show that both H and DO stadials led to decreased precipitation over northernmost South America while increased precipitation over the Andes. Interestingly, northeastern (NE) Brazilian precipitation exhibited significant increases during H stadials, but was characterized by small changes during DO stadials. Because DO stadials involved moderate slowdown of the Atlantic meridional overturning circulation (AMOC) relative to H stadials, we suggest that rainfall regime over NE Brazil was less sensitive to the AMOC reduction by shifting the mean position of the Intertropical Convergence Zone.

YSM 2 - Biosphere and ecosystem dynamics

The Batagay mega thaw slump reveals history of inland Beringia

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Beringia is a well known land bridge between Asia and America that numerously appeared during the Pleistocene low sea level stands. The East Siberian Sea shore line was shifted by 800 km to the north of its current position, which caused an increase of climatic continentality compared to the modern conditions.

Beringia has been subject of scientific research for several decades and is believed to be a main refuge area of Arctic flora and fauna and also the last asylum for woolly mammoth. Nowadays, mammoth-steppe or tundra steppe vegetation occupy only sparse areas in landscapes of Northeast Siberia; while during the Pleistocene in this unique biome coexisted animals, some of which are extinct now and others live in different climate zones.

Material available for palaeoreconstructions is available from permafrost exposures. A lot of data is published about the outcrops that

are located in nowaday's coastal zone. We would like to report the material from the inland permafrost exposure, that never experienced maritime influence, located in the Yana Uplands. This is the region in Northern Yakutia, Russia, where the Pole of Cold of the northern Hemisphere, Verkhoyansk, is found. In conditions perfect for permafrost preservation, 50 km from Verkhoyansk, forms the Batagay mega thaw slump. This is a 800 meter in diameter and 80 m deep permafrost exposure, where syngenetic deposits preserve organism remains.

We provide a detailed stratigraphic description of this profile and present results of cryolithological and geochemical analyses to deduce the genesis of the permafrost sequence. Radiocarbon and OSL dating results set the temporal frame of accumulation of the studied material from the Middle Pleistocene age till today.

Results of carpological, palynological, entomological analyses allow us to reconstruct vegetation patterns of Eemian Interstadial (120-127 ka BP)and Sartan Stadial (26 ka BP).

Drivers of vegetation change from the Šumava Region, central Europe in association with the 8.2 ka e

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The 8.2 ka event was a short-lived, cold climate anomaly that caused a wide range of both abiotic and biotic responses, such as changes in precipitation regimes, advances in glaciers, and changes in vegetation composition. Within central Europe, abrupt changes in vegetation composition may have been caused by cooler summertime temperatures resulting from less summer drought stress. However, at Prasilske Lake, Czech Republic, vegetation composition may have already been changing prior to the 8.2 ka event as a result of several large-scale landscape disturbances. A high-resolution pollen analysis was conducted between depths 1600-1650 cm, which corresponds to 6000-9000 cal yr BP in order to document the prior-to, during, and after ecological responses of the 8.2 ka event. Pollen analysis suggests a decrease in Picea pollen, and increase in Pinus pollen beginning around the 8,500 cal yr BP with a minimum of Picea pollen occurring around 8,200 cal yr BP. By using a multi-proxy approach using elemental XRF data, macroscopic charcoal and macrofossil analyses, preliminary results suggest disturbances may have helped facilitate vegetation change between 8000 and 9000 cal yr BP. For example, identification of several bark beetle remains suggests the presence of host specific Picea disturbance agents, which could have also helped facilitate the decline in Picea pollen. This study aims to investigate the main driver(s) associated with the change in vegetation composition at Prasilske Lake in order to understand both the local-scale and regional-scale drivers of vegetation change associated with the 8.2 ka event.

Macrophyte (Stuckenia) Analyses and ancient DNA from Lake Sediments - Lake Karakul, Tajikistan

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In order to understand the carbon cycle and potential carbon sinks it is crucial to understand limnological systems and their aquatic vegetation, which can play a major role in fixating carbon. However studies focusing on aquatic macrophytes in large lakes, especially from Central Asia, are rare. In this study we investigate a sediment core from Lake Karakul, Pamir Mountains (Tajikistan) in order to gain insights into changes in composition and productivity of submerged macrophytes and its relation to environmental parameters. We applied a multiproxy approach combining metabarcoding of ancient DNA to resolve the aquatic vegetation and elemental and isotopic measurements of Stuckenia cf. pamiricus leaf remains to determine palaeo-productivity changes. Our results show a pronounced dominance of Potamogetonaceae in the

analyzed ancient DNA sequences. Between 28.7 and 26.1 cal kyr BP Potamogetonaceae and Chara sequence reads where found, yet no Stuckenia cf. pamiricus macrofossils. From 26.1 and 17.5 cal kyr BP few macrophyte remains and high numbers of Potamogetonaceae sequences were recovered, while between 17.5 and 12.2 an increased number of Chara sequences and the absence of Stuckenia cf. pamiricus leaf remains was observed. High numbers of Potamogetonaceae sequence reads and many macrophyte remains are observed from 6.9 cal kyr BP onward. We suggest lake level changes of Lake Karakul as drivers for the Potamogetonaceae and Characeae dynamics and establish two phases of lake level high stands (28.7-26.1 and 17.5-12.2 cal kyr BP). Lower lake levels, comparable to present day, are reconstructed from 26.1 to 17.5 cal kyr BP and from 6.9 cal kyr BP until present. Macrophyte remain analyses reveale an medium paleao-productivity from 6.9 cal kyr BP and high palaeo-productivity from 2.2 cal kyr BP onward. Our conclusions are supported by other studies conducted at the lake and in surrounding regions.

Biogeographic distribution of extant Coccolithophores in the Indian Sector of the Southern Ocean

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Water samples from nine vertical profiles down to 110 m water depth and 19 samples from the sea-surface were studied for obtaining information on coccolithophore abundance and distribution across oceanic frontal regions of the Indian sector of the Southern Ocean. Sampling was performed along a north-south transect (between 39°S and 65.49°S, ~57.3°E) during the 4th Indian Southern Ocean Expedition (between 31st January and 18th February, 2010). Both coccospheres and coccoliths were counted separately using a Scanning Electron Microscope (SEM). A total of 39 taxa (including morphotypes, types and subspecies) were recorded as intact coccospheres with abundances reaching up to 745x103 coccospheres/l. In addition, 85 taxa (including varieties, morphotypes) were counted as coccoliths reaching up to 914×105 coccoliths/l. Emiliania huxleyi was recognized as the most abundant species, accounting for more than 86% of the total coccolithophore assemblage at each station. Elevated coccolithophore diversity was observed at the subtropical zone whereas high coccolithophore abundance was observed at the Subantarctic zone. A monospecific Emiliania huxleyi assemblage was recorded at and south of the Polar frontal zone. Three assemblages were recognized based on coccolithophore abundance and diversity. The assemblage of the Agulhas Retroflection frontal zone and Subtropical zone is highly diverse (39 taxa) and can be linked to relatively warm, high saline and oligotrophic waters. The Subantarctic zone assemblage is characterized by a reduced number (thirteen) of coccolithophore taxa, whereas Polar Frontal zone comprises a monospecific assemblage of E. huxleyi (preferentially morphotype C and B/C). Multivariate statistics indicated regions with elevated temperature and low nutrient concentration show high coccolithophore diversity whereas the regions with high nutrient concentrations and low temperature reduces coccolithophore diversity but increases monospecific E. huxleyi (morphotype B/C and C) abundance.

Linking fossil bark beetles to disturbance history of the Šumava National Park, Czech Republic

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Central European montane spruce forests are a niche environment, situated outside of their natural boreal range they are sensitive to climate stressors and disturbance dynamics. Recent outbreaks of Spruce bark beetle (Ips typographus) indicate that these pathogens are a major influence in the disturbance history of the region. Dendroecological records suggest that disturbance frequency and intensity of Spruce bark beetle has increased in recent decades (Svoboda et al., 2011). My study aims firstly to correlate

records from bark beetles (Scolytinae) with dendrochronological data to quantify disturbance history, while secondly to generate Holocene environmental and landscape reconstructions from subfossil beetle assemblages from the Sumava region in Czech Republic and the High Tatra Mountains in Slovakia. Both the Šumava region and the High Tatras have a long history of dendrology studies and many disturbance events have been dated. By linking paleoecological data (pollen, charcoal, diatoms, botanical macro remains and insect remains) from several regional lakes and forest hollows to the existing dendrochronological data we can extend our current knowledge on disturbance history beyond the temporal capability of dendroecology alone. Cores from lakes and forest hollows have been scanned for bark beetle remains and compared to the pollen and dendrochronological record. New methodology on retrieving bark beetle remains from lake sediments has been tested. Several species of bark beetles have been identified, among which the primary bark beetle Pytiogenes chalcographus is observed to respond to the 8.2 ka event. Consecutive results show that remains of Ips typographus are present in the record of one of the sites and that correlation to the dendrochronological record is possible. The results from two sites in the Šumava region will be discussed in this presentation.

YSM 3 - Human-climate-ecosystem dynamics

Late Holocene vegetation dynamics and disturbance regime in north Patagonia

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Despite several investigations on the long-term vegetation dynamic of the eastern side of the Andes, our knowledge is still limited, especially in northern Patagonia where the forest near the steppe ecotone is particularly divers. The distribution of the vegetation in this area responds to a west-to-east precipitation gradient, documenting that climate is the main control on the regional-scale variability in vegetation composition. However, natural and anthropogenic disturbances amplify or override the effects of climate on vegetation composition. Therefore, understanding the regional drivers, such as fire, volcanic eruptions and human activity and differentiating them from climate is important for climate reconstructions and nature conservation efforts. The aims of this project are to (i) reconstruct the late Holocene environmental history, (ii) identify the principal local and regional drivers of vegetation changes, (iii) compare the effect of disturbance events between sites at different altitudinal positions, and (iv) examine the fire-climate interaction across time. To answer these questions, we collected sediment cores from two lakes: Lake Bruja (40°14'S, 71°30´W; 1069m) and Lake Avutarda (40°23'S, 71°25´W; 1610m). Lake Bruja is situated about 150 m above a wide valley which is used for summer pasture of cows and horses that roam the forest around the lake, which is dominated by Nothofagus dombeyi and Nothofagus obliqua. Coring stopped after 130 cm due to a thick tephra deposition and the base of the core was dated to 3600 years ago. Lake Avutarda is located near the treeline of Nothofagus pumilio. Here a 110 cm long core was obtained and the bottom dated to 2800 years ago. Pollen and charcoal analysis, lithological description and estimation of organic matter content by loss on ignition were carried out on both cores. Preliminary results show frequent deposits of tephra, derived from volcanoes, mostly located in Chile. We are comparing the impact of these tephra depositions as well as fire events between the two sites. This work will contribute to an understanding of the importance of disturbance for the vegetation composition and help reconstruct changes in Holocene

climate near the forest steppe ecotone in Patagonia.

Late Holocene human-environment interactions in New Zealand: a biomarker approach

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The recent colonization history of New Zealand makes it an excellent test site for investigating the early impact of human activities on natural ecosystems. The arrival of humans around 700-800 yr BP is marked by a neat increase in fire activity and land clearance, as documented by charcoal and pollen records [1]. Here, the validity of biomarkers was tested in a multi-proxy study including three different categories of organic molecular markers. Results were compared with existing paleoecological data. Samples from a small alpine lake in the South Island of New Zealand (Lake Kirkpatrick, Otago), covering a time span of about 800 years (~AD 1153-1961), were analyzed for polycyclic aromatic hydrocarbons (PAHs) as combustion tracers, monosaccharide anhydrides (levoglucosan and its isomers, MAs) as specific markers of biomass burning and fecal sterols (FeSt) for the reconstruction of human/animal presence, organic matter input and chemical conditions of the basin. All tracers peak sharply and abruptly in a brief period centered at about AD 1350, which corresponds to the first increase in fire activity and decline in arboreal species in the South Island. Values decrease to background after ~AD 1400, until the beginning of the 19th century, when a huge increase is registered in FeSt after the European arrival.
Results are confirmed also by the FeSt record from Lake Diamond, not far from Lake Kirkpatrick, that is coherent with significant human presence and increased erosion and sedimentation during the 14th century. Such changes are consistent with the so-called AD 1300 event, a short period of increased precipitation and erosion observed in many records from Pacific Islands [2]. Whether natural changes affected human settlement and land use or vice-versa is matter of debate [3], and multi-proxy studies look promising in the reconstruction of such complex interactions and feedbacks.

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Fire and vegetation changes during Holocene recorded in Tibetan lacustrine sediments

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How land use changes have been influencing Holocene's climate is a hotly debated topic. Increasing awareness of The Early Anthropocene Hypothesis led to chemical and physical investigations of natural archives such as sediments, peat bogs, ice cores. Lacustrine sedimentary cores provide continuous records of large-scale and local environmental modifications, intelligible thanks to specific biomarkers that accumulated in these archives during past millennia. The asiatic region is one of the centers of the advent of agriculture and pastoralism, and it is a strategic area to explore biomarker distributions. In order to study the interactions between human, environmental changes and fire during the Holocene in Asia, we selected a small moraine lake called Paru Co, located in the South-Eastern Tibetan Plateau. We extracted 72 Paru Co sediment samples by Accelerated Solvent Extraction and analysed different organic molecular proxies by GC-MS and IC-MS. Firstly we aimed to reconstruct past fire history using a group of molecules called monosaccharide anhydrides (MAs).

Furthermore, we analysed polycyclic aromatic hydrocarbons (PAHs) as additional combustion proxies. To better understand the changes in vegetation and human presence at the lake shore we analysed n-alkanes and faecal sterols. The information obtained from these organic geochemical data needs to be complemented with archaeological findings, meteorological data and charcoal data. In this way we can contextualize in a regional setting the biomass burning events occurred in the Tibetan Plateau. Moreover, the association of past climate fluctuations with vegetation changes and possible human disturbances is allowed. From the MAs results we can see that the very high intensity of biomass burning recorded in the Early Holocene samples is parallel with the drier climate of the same period, following the deglaciation. The promptest results show that the local ecosystem and vegetation changes are in agreement with intensity's variations in the Indian Summer Monsoon rainfall.

Evaluating global ancient human impacts using archaeological and paleoenvironmental records

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Current Earth system modelling projects are limited by the lack of long-term quantitative estimates of population size, which, in turn, are needed to understand past global land use and land cover change. An open-access digital repository of global cultural and paleoenvironmental radiocarbon information, the Comprehensive Archaeological Radiocarbon Database (CARD), is currently being compiled with the objective of estimating the spatiotemporal distribution of humans in prehistoric time. The CARD has evolved from several regional compilations including Canadian (Canadian Archaeological Radiocarbon Database), Australian (AustArch) and European (CONTEXT, RADON) databases. This presentation will first serve as an introduction to the CARD and an explanation of the current state of the art of using archaeological radiocarbon dates as indicators of paleodemographic trends at a global scale. Examples will be given of regional and continental-scale results from North America which highlight distinct periods of population growth and decline, regions with continuous human occupation, as well as a rapid expansion across the entire continent after 13ka. Next, initial results depicting demographic patterns over the past 50ka across all continents will be presented. Among these results are 1) remarkable similarities between North American and Australian population curves which increase exponentially until European colonization after which they decline abruptly, 2) issues with comparing regions with complete (i.e., North America and Australia) and incomplete (South America, Eurasia) radiocarbon records, and 3) inconsistencies in Neolithic and Paleolithic databases. These results serve as a means of validating vegetation and land use models and discriminating between natural and human-induced environmental change. With time, these records will become more complete and new population estimates can be obtained to deepen our understanding of notable transitions in land use and land cover and the links between climate changes of the past and human demographic change.

Local physiognomic responses of local herbaceous biomass to climate and disturbance

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Moisture stress and disturbance are key drivers in the composition, structure and functioning of wetland herbaceous communities. Although rainfall and temperature have been shown to have strong influences on the composition and structure of herbaceous wetland communities, some physiognomic profiles of the wetland herbaceous community suggest that the interaction with disturbance agents (i.e., fire, herbivory and landuse) may lead to alternative vegetation structure(s). Multiple-proxy palaeoecological records provide a rich test-bed for investigating long-term changes and reorganization of ecosystems in response to variable climate and disturbance

regimes. Herbaceous community structure, herbivore utilization, soil disturbance and fire were investigated using grass phytoliths, dung spores, elemental analyses, and charcoal respectively from a wetland borehole located in a mesic grassland-savanna matrix in Vryheid, South Africa. We hypothesized that the utilization of productive wetland grassland would be higher in this region since the palatability of landscape grasses is of short duration in the year. We further hypothesized that local utilization of the productive grassland would cause a shift from tall unpalatable grasses to short palatable grasses due to a combination of fire and grazing at intermediate to high moisture stress. Our results suggest that local herbaceous biomass and structure at this site is principally driven by local moisture/ hydrology which affects the accessibility of the site to herbivores. In addition, local moisture/ hydrology affects the susceptibility and/ or flammability of local herbaceous biomass fuel mixture. However, the interaction between vegetation, moisture stress and disturbance intensity were related to changes in the abundance of short versus tall grasses. The sensitivity of biomass consumption by fire and herbivores to local moisture and vegetation structure can be used as a tool for identifying climate-vegetation-human interactions and also for testing the resilience of local herbaceous communities in small-medium sized sediment basins.

Tracking recent watershed changes in Vichuquén Lake (Central Chile) through δ15N signatures

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Stable isotope analyses of lacustrine organic matter is often used to reflect past environmental changes in aquatic ecosystems. Isotopic fractionation and variable sources of organic matter, however, hinder straightforward environmental interpretations of isotope signatures. To evaluate how stable isotopic values in surface lake sediments reflect modern isotope values in the lake watershed system and to assess the role of organic matter sources, limnological and diagenetic process we analysed δ15N and $\delta^{13}C$ values from soil and vegetation from watershed, particulate organic matter (POM) in water column and lake sediments from Lake Vichuquén (costal central Chile). Water samples from several different depths were collected and filtered for POM during summer and winter. Soil, watershed vegetation and surface lake sediments were also obtained. The main results show higher δ15N values from riparian vegetation (mean 8.1) and POM (mean 12.4) compared to surface lake sediments (mean 2.3). This may be due to shifting sources that contribute to lacustrine organic matter (watershed vegetation, soil, lacustrine). Recent changes in N cycling inferred from a short core (spanning the last ca. 600 yrs), include an upcore decreasing δ15N trend, perhaps caused by large-scale agricultural development and deforestation along with other anthropogenic activities.

Human disturbance and resilience of a tropical peatland in Sumatra, Indonesia

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Pressures on peatland in Southeast (SE) Asia due to land use and conversion escalate in the past few decades, following the increase in population demand for food, settlements and resources. In order to prevent loss and to maintain the important functions of this ecosystem, management strategies are urgently required. Historical information can provide valuable knowledge on ecosystem response to disturbance and their resilience. Thus, in order to create effective management strategies on peatland under rapidly changing global environment, it is important to include a historical perspective.

Unfortunately, knowledge on past disturbance of peatland in SE Asia remains a large gap, particularly of how past human interventions controlled vegetation composition and C accumulation in peatlands. Due to lack of

evidence, extensive human disturbance is considered to be novel. Thus, understanding the impact of peatland resilience to human-induced disturbance prevail to be a huge challenge.
By conducting palaeoecological study in a peatland on the coastal area of Jambi, Central Sumatra, we found strong evidence of extensive human disturbance from 1100 to 500 years ago, indicated by the openness in vegetation and decreased ecosystem ability to accumulate peat and carbon. The disturbance is noticed to be resulted from logging and grazing activities conducted by the inhabitants of Malayu Empire in the 9th to 14th century, whose temple remain is located close to the peatland. After the land abandonment as the Empire moved to the hinterland area, the record interestingly showed that ecosystem has recovered. In addition, the record suggests that socioeconomic and political condition was a significant indirect driver on peatland vegetation and its function.

Mapping livelihoods in West and Central Africa: changes in food-production from 1800 BC to AD 1500

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The changing land uses associated with the Iron Age transition in sub-Saharan Africa, such as increases in food-production and fuel consumption for metallurgy, may have had widespread consequences for regional climate, hydrology, biodiversity and ecosystem services that persist to the present. Quantification of these impacts and potential feedbacks is difficult however, because the archaeological and historical record is highly fragmented in time and space. We are approaching this problem from a modeling perspective by developing a classification system of subsistence and lifestyles based on a broad synthesis of archaeological, archaeobotanical, and ethnographic observations. A subset of this classification has now been mapped in time-slices across West and Central Africa where we focused primarily on several categories of agricultural land use which occurred heterogeneously in space and time. The main differences between these categories is the relative reliance on and variety of domestic species, and in turn the energy invested in them. While the particular crop or animal species utilized was partially dependent on environmental variables, diversification and intensification led to more stable agricultural results and an increase in the prevalence of farming societies. This paper presents the progress of this data synthesis and mapping process, using examples from the completed work on West and Central Africa, as well as the early stages of our work on East Africa.

16th-century America's population demise, land use and carbon cycle changes

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Large-scale land cover change occurred in the 16th-century Americas with the demise of the indigenous population from European-borne diseases. It has been hypothesized this led to an increase in the terrestrial carbon sink large enough to perturb global carbon dioxide levels. Here the historic evidence from colonial reports of the spread of the epidemics is reviewed in conjunction with updated charcoal and pollen records to disentangle the pattern of anthropogenically-driven land use change from natural forcings. We conclude that the decline in biomass burning was primarily anthropogenic, suggesting widespread near-cessation of agriculture and subsequent reforestation in the Neotropics during the 16th century. Existing land use estimates are reviewed against archaeological, historical and palaeoecological evidence to show differences in the distribution and magnitude of land use change between the reconstructions. We explore the magnitude of a potential carbon sink from reforestation following epidemic outbreaks. We suggest that the resulting carbon sink contributed substantially to the 2000-year minimum in atmospheric CO2 concentrations at around 1610 CE and potentially further amplified Little Ice Age cooling.

Drivers of regional and local boreal forest dynamics during the Holocene in northern Europe

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To better understand the processes behind boreal forest dynamics, different spatial and temporal scales need to be considered. Here, the relative importance of potential drivers of the Holocene boreal forest dynamics in northern Europe was quantitatively assessed using novel approaches in palaeoecological context. Fossil pollen data from lakes, reflecting regional vegetation, and small forest hollows, reflecting local vegetation, from Russia, Finland and Sweden was employed to reconstruct the long-term boreal forest composition. Statistical method variation partitioning was applied to assess the relative importance of climate, generated from a climate model and oxygen isotope data, forest fires, generated from sedimentary charcoal data, and human population size, derived from radiocarbon dated archaeological findings, on variation in long-term boreal forest composition. Wavelet coherence analysis was applied to investigate significance of individual forest fires on boreal forest dynamics.

The results clearly demonstrate that at regional scale climate is the main driver of long-term boreal vegetation changes. However, the role of climate is notably smaller at local scale and the influence of local site-specific characters increases. The relative importance of forest fires on long-term changes in boreal forest composition remain low both at regional and local scale. However, forest fires have a significant effect on the short-term changes in individual tree taxa. The relative importance of human population size was low in both the prehistorical and the historical time periods. However, this was first time that this type of data was applied to statistically assess the importance of human population size on boreal vegetation and the results should be considered cautiously. In all, these results highlight the complexity of processes behind the boreal forest dynamics and although climate drives the regional long-term boreal vegetation, disturbances and local bio-geophysical characteristics dictate the impact of climate on stand-scale boreal forest dynamics.

Holocene evolution of mangrove vegetation, palaeoclimate and sea level changes at the Chilka Lagoon

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High resolution multiproxy data have been generated from four radiocarbon dated sediment profiles in order to reconstruct Holocene evolution of mangrove vegetation in relation to sea-level changes and concurrent climatic fluctuations from the Chilka Lagoon, Odisha, India. It is the largest brackish water lagoon in Asia, situated in the humid tropical climatic zone along the east coast of India. The results indicate three phases of mangrove development from the study area: between 11000 to 8800 yrs B.P.; 8800 to 5500 yrs B.P. and 2500 to 2200 yrs B.P. Development of mangroves at the Chilka Lagoon began since 11000 yrs B.P indicating the initiation of warming phase. Diversification of mangrove forests at the study site took place during 8800 to 5500 yrs B.P. During this period, increase in mangroves and reduction in midland taxa are recorded. Rhizophoraceae became the dominant vegetation followed by Sonneratia apetala, Aegialitis rotundifolia, Xylocarpus granatum, Aegiceras corniculatum and Acanthus ilicifolius. Marine elements, such as tintinnids, foraminiferal linings and dinoflagellate cysts are also recovered in good values. The overall palynological assemblage suggests the prevalence of deltaic environment with insurgent sea tides periodically inundating the area. Thischange to mangrove dominated vegetation was due to sea-level rise and warm moist climate, which provided conducive environment for the optimum

development of mangrove forests. The rich mangrove vegetation started deteriorating after 5500 yrs B.P. due to changes in sea-level. An intertidal environment reappeared for short span of time around 2500 to 2200 yrs B.P., resulting in the rejuvenation of the mangroves. Around 2200 yrs B.P., loss of the intertidal environment occurred due to relative sea-level fall triggered the disappearance of the mangroves from the area. The deterioration of mangroves during late Holocene in the Chilka Lagoon was a result of change in climate towards more aridity, relative sea-level fall and accelerated by human activities.

Late Holocene vegetation responses to climatic and disturbance drivers in Western Indian grasslands

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Tropical semi-arid and arid grassland biomes or Savannas are one of the most important terrestrial biomes in terms of their extent, economic and ecological importance. This ecosystem deserves much attention in the context of current day scenarios of changing climatic, edaphic, grazing and fire regimes, to all of which this system is especially sensitive. In this study, mid late Holocene dynamics of semi-arid vegetation and drivers of vegetation change are assessed based on the reconstruction of past vegetation, climate, herbivore abundance and fire events. This is done by analysing multiple proxies such as pollen, phytolith, stable isotopes of carbon, geochemical proxy- Al2O3, fungal spores and charcoal from sediment cores and by determining age of the sediment layers. Results show that Banni was composed mostly of C3 vegetation with higher abundance of pollen types (Syzygium, Acacia and Combretaceae) and phytolith morphotypes (tree/shrub) that indicate woody savanna from ~5000 to ~2500 cal yr BP, after which there was a decline in C3 vegetation and an increasing trend in grass phytolith. Since ~700 cal yr BP, there was a decline in C4 vegetation and grass phytolith abundance and an increase in leguminous taxa. These vegetation dynamics were coincident with rainfall changes from more mesic conditions during ~5000 to ~2500 cal yr BP to more arid conditions towards the present as indicated by Al2O3 data. The period of increase in C4 vegetation also coincided with a period of increased biotic disturbances in the ecosystem, either from fire or herbivory or both. In the current scenarios of global warming, recurrent drought events and increased anthropogenic use of grassland ecosystems, such studies can inform us about the future trajectories of these ecosystems.

Tropical climate dynamics through the Holocene using varve analysis from Yaal Chac, Mexico

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Using varved sediment cores from lake Yaal Chac, Mexico, sub-annual climate is reconstructed through the mid-Holocene (~8.8-5.1 ka cal BP) using microfacies analysis and their geochemical composition. High seasonality at the site drives varve formation; the annual wet and dry seasons lead to the deposition of organic matter and autochthonous calcium carbonate respectively. By developing a mechanistic model of varve formation, the environmental conditions required to cause changes in the observed sedimentology can be inferred.
The varve microfacies record displays a long-term decline in varve thickness between ~8.8-5.1 ka cal BP, and a switch from aragonite to calcite deposition, generally associated with a decreasing evaporation / precipitation (E/P) ratio. There is a strong correlation between carbonate laminae thickness and total varve thickness. Continuous varve deposition ends abruptly at ~5.1 ka cal BP when fresher water no longer exceeds the carbonate solubility level on an annual basis; although carbonate precipitation events return periodically through the later parts of the record and are visible in near-surface sediments today. Depletion of oxygen isotopes from the

carbonate material at 5.1 ka cal BP supports the inference of a system switch to fresher lake water at this time.
Climate is inferred to drive carbonate precipitation and mineralogy change during the varved sequence in the early-mid Holocene indicating a wetting climate, which has also been observed in other palaeorecords across the Yucatan. Future work aims to further investigate the abrupt switch in sedimentology at ~5.1 ka cal BP. This likely relates to a threshold change to the catchment's hydrology acting to reduce carbonate precipitation, but is potentially driven by complex interactions between groundwater, climate and catchment stability, the latter increasingly impacted by regional human activity. The short-lived re-emergence of calcareous varves and peaks in Ti deposition in the late Holocene are hypothesised to be associated with Mayan activity.

Climatic & anthropogenic drivers of past ecological dynamics in lake Montcortés (Iberian Peninsula)

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Lakes with varved sediments are especially well suited for high resolution paleoecological reconstruction because they assure accurate time control. Multi-proxy studies at high resolution provide opportunities to examine frequency and magnitude of abrupt events in response to either climatic change or human impact. Also, these data could be used to reconstruct the past by comparison with historical records and using instrumental data to carry out quantitative paleoclimatic reconstruction. Here we present a study aimed to assess climatic variability of the last 500 years and carry out a quantitative paleoclimatic reconstruction. To do so, we chose Montcortès Lake (Southern Central Pyrenees, Spain) which has a continuous varved record that allows high resolution time control. The selected time frame covers the transition from the Little Ice Age to the industrial era, where climate variability also responds to anthropic origin and instrumental climatic data are available. We focus on understanding how sedimentation processes work related to climate and environmental conditions, by means of an exhaustive monitoring of the lake and using traps to collect sedimentary and modern analogs for pollen and diatoms. To assess the climatic variability, we carry out highest resolution paleoclimatic reconstruction achieved so far in the record using pollen and diatoms. Biological multi-proxy data covering the last 80 years will be calibrated with instrumental data to extract transfer function and quantitatively reconstruct the climate. This contribution will help to propose possible scenarios and responses of the ecological communities to current climate change as well as to assess possible changes in the lake's behavior affecting water quality under the influence of global warming. The data obtained in this study will be used to feed data bases to validate climatic change modeling.

Pollen sources in studies of camelid coprolites from Patagonia (Argentina)

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Palynological studies on Holocene coprolites provide information about palaeodiets, seasonality and palaeoenvironment. The elucidation of the source of the coprolites pollen is a main issue to interpret what and how past facts happened. The aim of this study is to analyze the source of the pollen of present day Lama guanicoe feces and camelid coprolites. For this, feces and coprolites post-depositing pollen contamination and the plant surface contamination, which are part of the L. guanicoe's diet, were evaluated. The feces and plant were collected in the area near the sites CCP5 and CCP7 (47°57' S 72°05' W, 900 mamsl), Perito Moreno National Park. Moreover, coprolites collected in CCP5 and CCP7 dated by 14C between ca. 9640 and 2740 yr BP, were studied. Feces and coprolites were divided into outer and inner subsamples and extracted pollen from both fractions for analyses. Pollen extraction of the

plant surface of Mulinum spinossum, Empetrum rubrum, Senecio filaginoides and Nardophyllum obtusifolium, were done. The results showed differences in the pollen concentration between subsamples of feces that could be linked with the pollination season. Coprolites evidenced a greater Nothofagus (anemophilous) pollen concentration in the outer surface than in the inner ones and certain taxa were only registered in a single part. Plant surface showed a high concentration of pollen of the mother plant, and a low concentration of other anemophilous and zoophilous taxa. A separate pollen analysis of the outer and inner parts of modern feces and coprolites yields information referred to pollen contamination; thus, the diet items of the vegetation not consumed by the organisms can be discriminated. These results are a new contribution to palaeoecological studies of Patagonia during the Holocene and highlight the importance of considering the taphonomic processes, which would be acting in the building of the pollen record of modern feces and coprolites.

YSM 4 - Abrupt changes and threshold responses

A Late Pleistocene Meltwater Routing Record from the Gulf of Mexico

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Marine sediment cores in the Gulf of Mexico contain an archive of terrigenous sediment from the Mississippi River over time. This sediment also maintains a unique geochemical signature of their primary source location and can be used to fingerprint where water is being derived within the Mississippi drainage. During the last glacial period, routing of freshwater from the Laurentide Ice Sheet was predominantly restricted to four primary drainage areas and largely influenced by the location of the southernmost extent at ~45N. Which drainage the water discharged had a profound influence on North Atlantic Deep Water formation, and therefore determining the timing of the freshwater routing for the drainages can provide better constraints on past climate changes during the last glacial period.

To shed light on the meltwater history from the ice sheet to the Mississippi River drainage, sediment cores from 50 sites in a network across the Gulf of Mexico have been

analyzed for geochemical composition using XRF core scanners (ITRAX and Avaatech), which offer a fast, non-destructive method to capture relative elemental counts. The sediment cores extend from present into the last glacial, and preliminary age-depth models for each core are created by cross-correlation based on sediment density, magnetic susceptibility, and biostratigraphy. XRF data show discrete packages of sediment heavy in lithic fragments and Ti and Si, characterizing meltwater plumes of freshwater discharged from the Mississippi River, thinning in thickness away from the mouth of the river. Cores located in distal positions (~1000 km) from the Mississippi River record several glacial cycles and show the extent of the meltwater plumes. Combining XRF data with an extensive network of cores allows a unique geochemical signature of the Mississippi River to be identified, and maps its attenuation across the Gulf of Mexico in three dimensions for the first time.

Changes in the western South Atlantic and the adjacent continent during Heinrich Stadials 3 and 2

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The Brazil Current (BC) is formed at the bifurcation of the South Equatorial Current and interacts with the southeastern Brazilian continental margin in the western South Atlantic. Sea surface temperatures of the BC partially control the intensity and position of the South Atlantic Convergence Zone, which represents one of the main components of the South American Monsoon System. This atmospheric system is responsible for summer precipitation in a large sector of South America. However, the few upper-ocean paleoceanographic records available from the western South Atlantic do not allow a detailed reconstruction of the changes that happened in the BC during the last glacial cycle beyond the Last Glacial Maximum. Here, we have reconstructed sea surface temperatures (SST) in the BC region around 32°S during Heinrich Stadials (HS) 3 and 2, as well as the impacts of SST changes on the climate of southeastern South America. To this end, we investigated marine sediment core GeoB6212-1 collected from the southern Brazilian continental margin, a site under the influence of the BC. We produced an age model based on 14 14C AMS ages, downcore records of stable oxygen isotopes and Mg/Ca in tests of planktonic foraminifera, and X-ray fluorescence of the bulk sediment. During HS (notably during HS2), our records show decreases in the sea surface temperature and salinity, and marked increases in sedimentation rates as well as in ln(Ti/Ca) and ln(Fe/Ca). We relate these changes to the weakening of the Atlantic Meridional Overturning Circulation and the strengthening of the South American Monsoon System. The occurrence of a w-structure (reflecting the succession of SST maxima and minima) in our HS2 records as well as in North Atlantic and South American records, suggest that one such structure is a pervasive feature of HS2.

Holocene rapid climate changes reflected in NE and CE European charcoal records

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The Holocene climate has undergone several marked short-term variations i.e., climate shifts occurring within centuries or even decades, known as rapid climate changes (RCCs). Evidence from multiple records indicates a wide-ranging manifestation of RCCs in Europe, with contrasting spatial characteristics and impacts. However, little is known about the spatial sensitivity of fire activity to short-term Holocene climatic variations.

Here we explore the evidence of Holocene rapid climate changes in three high resolution macroscopic charcoal records from CE and NE Europe, with the purpose to examine similarities and differences in the timing and trends of fire activity. Specifically, we compare burning responses to RCC's between the more humid and more continental parts of Eastern Europe, also taking into account vegetation dynamics from

published literature as a general estimation of fuel abundance.
Our charcoal records show evidence for increases in fire activity at all sites, centered on 8.2 ka, 5.1 ka, 3.9 ka, 2.6 ka, 1.1 ka and last 200 yrs. However, intervals of rapid climate change are marked by high amplitude increases in the NE Europe charcoal record, whereas in the CE European records this pattern is visible with lower amplitude.
Our insight in the spatial and temporal relationships between RCC's and past fire activity might contribute to a deeper understanding of the impacts of future climate changes on biomass burning.

Water masses and circulation in the Denmark Strait during Dansgaard-Oeschger events

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The mechanisms responsible for millennial-scale oscillations associated with Dansgaard-Oeschger (D-O) events during marine isotopic stage 3 are not fully understood. While this climate instability appears connected to perturbations in ocean circulation patterns and sea ice cover, it is unclear what role the overturning circulation played in driving abrupt changes. The Denmark Strait is a key region capturing the exchange of cold surface polar waters and warmer intermediate North Atlantic waters and a major conduit for waters feeding the deep western boundary undercurrents of the North Atlantic. Hence the area is a critical region where-from data can be obtained to elucidate key mechanisms related to D-O events.
Here we examine the configuration of D-O events 8-5, recognizable by their cyclic patterns of rapid change from cold stadials to warm interstadials and their gradual retreat back into stadial conditions. To capture these abrupt events, the hydrography in the Northern side of the Greenland-Scotland Ridge is investigated using paired Mg/Ca and δ18O analysis from the benthic foraminifera C. neoteretis, to reconstruct a unique palaeo-temperature and seawater δ18O that can be correlated to ice core and other marine proxies.
We have also measured the B/Ca ratios of the same samples for reconstructing past ocean carbonate system at intermediate depth. The sampling increments we use allows for a high 30-year temporal resolution that throw light on the chain of events characterizing these swift warmings. This provides new insight into the characteristics of hydrographic changes and associated variations in the exchange over the Denmark Strait across the transitions from stadials to interstadials between 40-30 ka, and how these relate to atmospheric changes and sea ice changes at coeval times.

YSM 5 - Modeling

Role of sediments in controlling the dynamics of paleo-ice sheets

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The motion of glacial ice is predominantly controlled by basal conditions, which include a variety of parameters such as ice rheology, temperature, water content, the presence of sediments, and topography. Soft sediment deformation has long been hypothesized to be a dominant control on the size and dynamics of temperate ice sheets such as the Laurentide Ice Sheet. The transition from hard-bedded regions (areas that lack significant sediment cover) to soft sediment areas put a limit on the maximum volume of these ice sheets. When the ice sheet margin reached soft sediment cover, it may have caused the ice sheet to surge, with global-scale climatic impacts. Current generation ice sheet models only have limited control on how sediments modify the behavior of an ice sheet. We present a model of sediment deformation that can take into account the thickness, lithology and hydrology at the base of the ice sheet using the Parallel Ice Sheet

Model (PISM). We assess how changes in sediment properties affect the advance and retreat of the ice sheet, including standstills in the margin when the ice sheet becomes restricted to the hard-bedded interior areas. We apply this model to the Wisconsin Glaciation (~85-11 kyrs ago) of the Laurentide ice sheet. We show how the distribution of sediments affect its growth and retreat. We specifically focus on how the soft bedded Hudson Bay impeded the growth of the ice sheet, up to the lead up to the Last Glacial Maximum. We also investigate the relationship between Dansgaard–Oeschger and Heinrich events and the basal dynamics of the ice sheets.

Antarctic Last Interglacial Isotope Peak in Response to Sea Ice Retreat not Ice Sheet Collapse

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Several studies have suggested that the Antarctic Ice Sheet was the primary contributor to sea level rise during the last interglacial (LIG; 130,000 to 115,000 years ago), most of which is hypothesized to have come from the unstable West Antarctic Ice Sheet (WAIS). Collapse of the WAIS would contribute ~3.5 m to the 5-9 m sea level rise reconstructed for the LIG. The prevalent hypothesis is that WAIS loss coincided with the peak Antarctic temperature and stable water isotope values from 128,000 years ago (128 ka); very early in the last interglacial. Using Bayesian multivariate linear regression and a statistical model comparison to combine isotope-enabled climate model simulations with Antarctic ice core data, we show that WAIS loss is not consistent with the isotopic evidence at 128 ka. Instead, a 65 ± 7 % retreat of Antarctic winter sea ice area best explains the 128 ka ice core evidence. This finding of a dramatic retreat of the sea ice at 128 ka demonstrates the sensitivity of Antarctic sea ice extent to climate warming. These results may also provide supporting evidence for WAIS loss and sea ice build up later during the LIG.

Land use in Classical Antiquity: How good are the global datasets? A case study in Roman Switzerland

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The impact of humans on the landscapes of Europe in Classical Antiquity has been poorly quantified to date. Most global scenarios of Anthropogenic Land Cover Change (ALCC), e.g., HYDE and KK10, suggest that humans had relatively little influence on land cover during the Imperium Romanum, while documentary sources and archaeological data imply that much of the Mediterranean and surrounding areas were severely impacted by human activities by this period. In order to address this discrepancy between models and observations, we have synthesized the archaeological evidence of ancient agriculture and land use, primarily based on archaeobotany, archaeozoology, and palynology, from the 1st century B.C.E. until the 3rd century C.E., the so called *Pax Romana* period, for the area covering contemporary Switzerland. Using these data, we reconstruct per capita land use in the principal regions of Switzerland: the Alps, the Plateau and the Jura, and the diversity evident between different types of occupation including coloniae, civitas capitals, military forts, villae and rural settlements. Where the archaeological record does not record necessary information, such as quantifying productivity and fertility, the literary record, ethnographic studies and modern scientific studies are utilised in order to develop a holistic view of ancient land usage and human-environment interactions. Our data synthesis is used to inform a quantitative model of human-environment interactions that allows us to test hypotheses and assumptions about land use in the ancient world. The major settlements of Augusta Raurica and Aventicum, as well as the military fortress of Vindonissa, show the highest degree of impact on the surrounding territory, though this would have been dispersed across the countryside through trade and production at neighbouring sites in the region. However, the greatest extent of land usage is presented by Alpine and rural

settlements where caprines and cattle dominate the assemblages respectively. By grounding land use models in the archaeological record, we can evaluate models, while at the same time provide a practical and flexible tool for estimating ALCC over larger landscapes.

Glacial-Interglacial Variations in the Carboncycle

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The understanding of the mechanisms governing glacial-interglacial variations in atmospheric CO2 remains limited. Recent ice core studies on d13CO2, now covering the period from 155 kyrBP to present, reveal an offset in the d13CO2 record between MIS6 (~155 kyrBP) and the LGM (~21 kyrBP) (Eggleston et al., 2016, Paleoceanography). A similar offset is also found in marine sediment records. What is the reason for this offset in d13C in the atmosphere-ocean system?
This question is addressed by performing novel 100-kyr long carbon isotope-enabled simulations with the Bern3D-LPX Earth System Model of Intermediate Complexity. Potential mechanisms such as changes in land carbon inventory, the weathering rate of organic matter by erosion, or Neogene ocean cooling are changed in a step-like manner. Evolution of climate, different physical and biogeochemical tracers, and their fluxes through the atmosphere, ocean, ocean-sediment, and land biosphere model components is monitored. Characteristic spatial and temporal patterns are extracted by Principal Component Analysis.
Results suggest that differences in land biosphere carbon inventory are hardly responsible for the d13CO2 offset, but rather long-term imbalances in the weathering-burial fluxes.
The d13CO2 signal from the release of isotopically-light land carbon evolves differently than that of CO2. Initially, the d13CO2 perturbation is removed much faster than the CO2 perturbation as gross exchange with the land biosphere and the ocean dilute the isotopic signal. On millennial to 100-kyr timescales, the 13C perturbation is removed by dissolution of isotopically-enriched CaCO3 from sediments and the burial of biogenic particles with perturbed d13C signature.
Comparison of model results with a multitude of proxy data, including for example marine carbonate-ion concentrations (Yu et al., 2013 - Quaternary Science Reviews), d13C from ice and ocean sediments, or atmospheric oxygen (Stolper et al., 2016 - Science) will further help to constrain mechanisms of climate-biogeochemical changes and feedbacks.

Reconstructing Greenland Ice Sheet Dynamics During the Last Deglaciation

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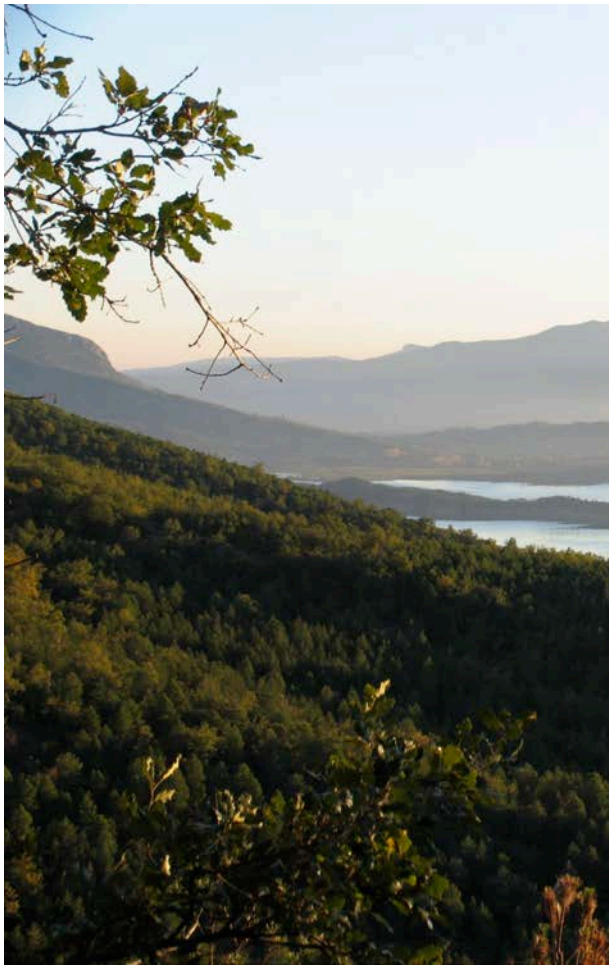
Sea level rise (SLR) is one of the most profound social and environmental issues facing humanity today, yet the response of polar ice sheets to future warmth remains uncertain. Disintegration of the Greenland Ice Sheet (GrIS) would raise global sea level by ~7 meters, and many Greenland outlet glaciers are already undergoing rapid retreat. The last period that saw such dramatic, sustained retreat of the GrIS was the last deglaciation, when the ice sheet retreated from its Last Glacial Maximum extent and contributed >2 m to global SLR. Thus, the deglaciation provides a unique test case for understanding the dynamics of ice- sheet retreat using a three-dimensional numerical ice-sheet model. Here we use a three-dimensional ice-sheet model at 10km resolution over Greenland to simulate the last deglaciation. Our simulations show that the GrIS grew to a maximum volume ~50% greater than present around 21,000 thousand years ago (21 ka) and reached a minimum volume ~10% smaller than present around 8 ka. We compare our simulations against data of margin retreat and show that the model captures the reconstructed progression of terrestrial deglaciation, with ice disappearing earliest in eastern sectors of the ice sheet and later in western sectors. We force the model with varied atmospheric and oceanic forcing scenarios (within the range of

uncertainty of paleoclimate data) and find that the timing and rate of deglaciation in south Greenland is extremely sensitive to the magnitude and timing of oceanic warming. Our results identify the ice-sheet response to rapid oceanic and atmospheric warming, and highlight particular regions (especially Nuuk and Paamiut in southern Greenland) that were especially sensitive to past climatic changes. We demonstrate that ice-sheet history is a valuable tool for understand ice-sheet retreat dynamics and should be considered when making projections about ice-sheet response in a warming climate.

YSM 6 - New technical and methodological development in past global changes



Automatization of an inverse surface temperature modelling procedure for Greenland ice cores

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In order to study Northern Hemisphere climate interactions and variability during the Holocene, access to high resolution surface temperature records of the Greenland ice sheet is an integral condition. Surface temperature reconstruction relies on firn densification combined with gas and heat diffusion [Severinghaus et al., (1998)]. To model the firn characteristics we use the model developed by Schwander et al. (1997). A theoretical δ15N record is generated for different temperature scenarios and compared with measurements by minimizing the mean squared error (MSE). The goal of the presented study is an automatization of this inverse modelling procedure. To solve the inverse problem, the Holocene temperature reconstruction is implemented in three steps. First a rough first guess temperature input (prior) is constructed which serves as the starting point for the optimization. Second, a smooth solution which transects the δ15N measurement data is generated following a Monte Carlo approach. It is assumed that the smooth solution contains all long term temperature trends and (together with the accumulation rate input) drives changes in firn column height, which generate the gravitational background signal in δ15N. Finally, the smooth solution is superimposed with high frequency information directly extracted from the δ15N measurement data. Following the approach, a high resolution Holocene temperature history for the Gisp2 site was extracted (posteriori), which leads to modelled δ15N data that fits the measurements in the low permeg level (MSE) and shows excellent agreement in timing and strength of the measurement variability. To evaluate the reconstruction procedure different synthetic data experiments were conducted underlining the quality of the method. Additionally, a second firn model [Goujon et al. (2003)] was used, which leads to very similar results, showing the robustness of the presented approach.

Strip-bark morphology and radial growth trends: Considerations for dendroclimatic reconstructions

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Some of the oldest and most important trees used for dendroclimatic reconstructions develop strip-bark morphology, in which only a portion of the stem contains living tissue. The potential effects of strip-bark morphology on radial ring widths, and subsequent climate reconstructions, are not well understood. Strip-bark growth patterns could have the potential to drastically alter our understanding of recent climate change relative to past variations. In this study, we compared radial growth of living whole-bark (i.e. active cambium all around the stem) and strip-bark Pinus sibirica trees growing on an ancient lava flow in central Mongolia. Ring widths of strip-bark and whole-bark trees show common year-to-year variability, however, the strip-bark trees contain long-term growth trends not evident in the whole-bark trees. In particular, the average growth rate of strip-bark trees significantly exceeds whole-bark trees during the 20th and 21st centuries. Further, trees with extreme cases of strip bark (>40% stem dieback) have a higher mean growth rate, and a higher positive trend in mean ring width from 1800-2014, as compared to trees with a smaller percentage of strip bark. These findings suggest that the morphology of long-lived trees can influence ring-width patterns through time. Potential morphological effects on radial growth should be considered when including and standardizing strip-bark trees for interpretation of past climate.

Triple oxygen isotopes in carbonate sediments: Insights on East African water balance since 500 ka

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Carbonate oxygen isotopes (δ18O) are among the most powerful tools for reconstructing terrestrial hydroclimate, but the complex set of processes influencing carbonate δ18O adds uncertainty to past climate interpretations. Kinetic fractionation via evaporative forcing has been particularly difficult to constrain. Triple oxygen isotopes have recently emerged as sensitive recorders of evaporation, specifically via the secondary parameter 17O-excess (e.g. Landais et al., 2010), and analytical advances allow for its precise measurement in carbonates (Passey et al., 2014). When measured in tandem with clumped isotope thermometry [T(Δ47)] and traditional stable isotopes, carbonate 17O-excess can reveal the extent of evaporative forcing and be used to estimate the isotopic composition of unevaporated source waters.
Here we apply this novel proxy approach to reconstruct local water availability and regional hydroclimate over the past 500,000 years from sediment cores recently recovered by the Olorgesailie Drilling Project from the southern Kenya Rift Valley, where local variations in water balance likely influenced human evolution and migration in eastern Africa. Carbonate δ18O values average -0.4 ±1.9 (n=141), while T(Δ47) and reconstructed parent water δ18O values range from 14-32°C and -1 to 5, respectively (both n=28). The range of 17O-excess values is approximately 150 per meg (n = 29), exceeding that reported for freshwater sources today (≤ 80 per meg; Luz and Barkan, 2010; Li et al., 2015). We observe a strong negative correlation between 17O-excess and δ18O values, consistent with evaporative enrichment of heavy isotopes in water. Together, these results suggest evaporation within the basin is an important control on the Olorgesailie carbonate δ18O record. With this study, we distinguish local

from regional controls on hydroclimate variability in eastern Africa since 500 ka and demonstrate the crucial insight triple oxygen isotopes provide to carbonate δ18O records, particularly when evaporation is expected to play a significant role on water balance.

New techniques in palynology: Using FTIR and pollen morphology to classify Eucalyptus Pollen

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Traditional taxonomic methods for pollen identification in Quaternary palaeoecology based on morphology are highly time consuming and can also be limited by taxonomic precision. Two separate approaches have the potential to improve methods of pollen analysis in sediment cores. Automatic classification and identification using the Classifynder system (Holt et al. 2011; Lagerstrom et al. 2015) has the potential to use detailed morphological measurements and machine learning techniques to distinguish pollen types at higher levels of taxonomic resolution. Fourier transform infrared (FTIR) spectroscopy is an alternative approach which can providing information on chemical composition of pollen by characteristic spectral bands and features (Zimmermann and Kohler 2014; Dell'Anna et al 2009). Pollen infrared spectra contain specific signals from lipids, carbohydrates, sporopollenin and other cell wall biopolymers that can be used to fingerprint species. Combined, these two approaches open new and exciting prospects for the classification of pollen.

We have characterized 4 Eucalyptus species from Bega Swamp, Australia using morphological as well as chemical composition data. Fresh pollen samples were gathered from 4 species of Eucalyptus dominant around Bega Swamp which are difficult to classify using standard morphological approaches (E. fraxinoides, E. fastigata, E. radiata and E. dalrympleana). Taxa were analyzed using both FTIR and with the automated Classifynder system was used to gather morphological information on the collected pollen. Using multivariate statistical analyses, the chemical composition of the pollen was determined as well as characteristic spectral bands for the different species. The spectral data is combined with the morphological results to identify differences between the species that can be used as a new technique to automate pollen classification based on morphology and chemistry of species hard to identify with conventional light microscopic methods.

Using co-located lake and bog paleohydrologic records to improve proxy climate interpretations

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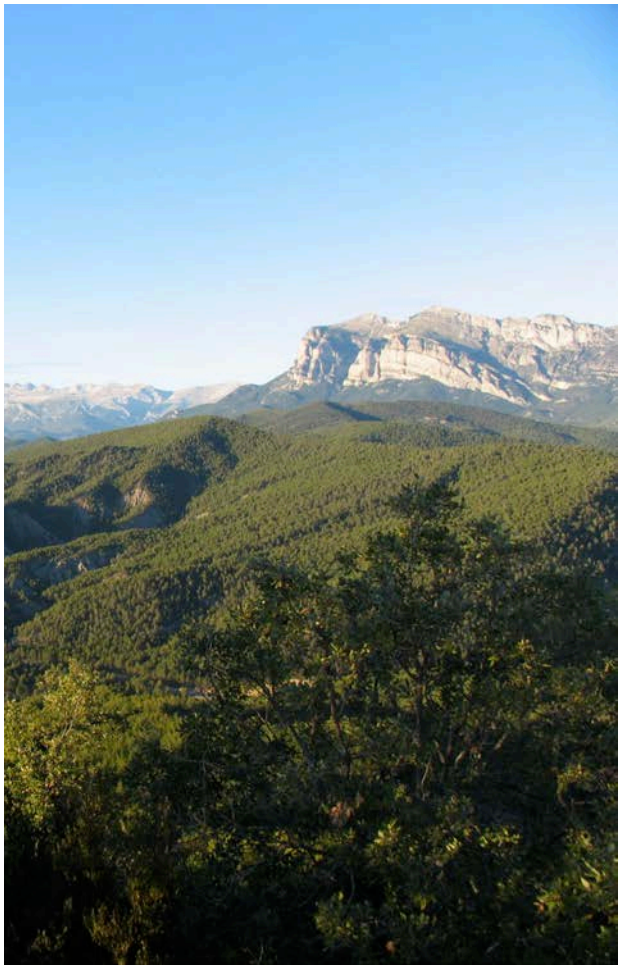
Terrestrial hydrologic variability over the Holocene can be documented by many different proxies. In particular, in the northeastern United States two key methods are sedimentological lake level reconstructions and testate amoebae inferred water table depth reconstructions from ombrotrophic peat bogs. There is an existing network of both of these types of reconstructions, but they have never been used in the same location. Thus, it is difficult to directly compare the resulting reconstructions because potential proxy differences are confounded with regional climatic differences. Here we present a new lake level record from Giles Pond, Aurora, Maine, US and a new bog record from Caribou Bog, Old Town, Maine, US. These records from the southern Maine highlands are located approximately 40 km apart and overlap in time over the past approximately 7000 years and provide the first directly comparable pair of co-located records. In comparing these two very different types of hydroclimate proxies we are also leveraging their unique strengths, especially in the frequency domain. Lake level records best preserve centennial-to-millennial length events and trends whereas bog records are best at decadal-to-multidecadal frequencies. So by having the two types of records in the same place we can develop a multi-scale reconstruction of past hydroclimate variability that provides texture to the individual

reconstructions that is not possible otherwise. Our approach of developing new, co-located records is a critically important and underused approach to better understand the fidelity of these methods that we use to reconstruct past climate.

ORALS

YSM 1 - Climate system dynamics



Mean ocean temperature evolution in the past 40,000 years from ice core noble gas thermometry

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The amount of heat stored in the ocean is the most robust measure of the integrated energy imbalance of the Earth that accompanies glacial-interglacial climate swings. For the current anthropogenic warming, more than 90% of the excess heat stored by the Earth over the last 50 years is found in the ocean. The history of ocean heat content is thus a central parameter in the reconstruction of global climate forcing and response.
Local deep water temperature has been reconstructed using sediment cores, but a truly global signal is difficult to synthesize. The novel method of ice core noble gas thermometry allows us to reconstruct global mean ocean temperature (GMOT) based on simple physics. Because noble gases are passively cycled through the atmosphere / ocean system, and because each gas species has a specific temperature dependent solubility, noble gas ratios in the atmosphere represent a direct, physical proxy for GMOT. After correcting for fractionation effects that happened in the firn column prior to the air getting trapped in the ice matrix, measurements of noble gas elemental ratios in ice cores can thus be used to estimate past GMOT.
We present a record of GMOT obtained from EDC ice core samples spanning the last 40,000 years in roughly 1,000 year resolution, highlighting the warming during the deglacial transition. The Last Glacial Maximum GMOT is estimated to 2.6°C colder than present, in good agreement with sediment core oxygen isotope and pore water fluid reconstructions. The early Holocene was slightly warmer than present by approximately 0.5°C. The GMOT record shows a remarkable correlation with Antarctic temperature, suggesting that the Southern Ocean is an important driver of temperature change in the deep ocean.

Causes of ice-age intensification across the Mid-Pleistocene Transition

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HASENFRATZ, Gerald H. HAUG, Samuel L. JACCARD, Alfredo MARTÍNEZ-GARCÍA, Heiko PÄLIKE, Richard D. PANCOST, Philip F. SEXTON, Paul A. WILSON

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During the Mid-Pleistocene Transition (MPT; 1200 - 800 thousand years ago, kyrs) Earth's orbitally paced ice age cycles intensified, lengthened from ~40 to ~100 kyrs, and became distinctly asymmetrical. Testing hypotheses that implicate changing atmospheric CO2 as a driver of the MPT has proven difficult with available observational records. Here we use orbitally-resolved, boron-isotope CO2 data to demonstrate that the glacial-to-interglacial CO2 difference increased from ~43 to ~75 uatm across the MPT, mainly due to lowering of glacial-stage CO2 levels. Through carbon cycle modelling we attribute this decline primarily to the initiation of substantive dust-borne iron fertilisation of the Southern Ocean during peak glacial stages. We also observed a two-fold steepening of the relationship between sea level and CO2-related climate forcing that is suggestive of a change in the dynamics that govern ice sheet stability, such as that expected from subglacial regolith removal. We argue that neither ice sheet dynamics nor CO2 change in isolation explain the MPT. Instead, we infer that the MPT arose from a change in ice sheet dynamics, and that longer and deeper post-MPT ice ages were subsequently sustained by carbon-cycle feedbacks related to dust fertilisation of the Southern Ocean as a consequence of larger Northern Hemisphere ice-sheets.

Instant responses of Indian Ocean monsoon to high-latitude northern Atlantic during the last 16 ka.

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During the last decade, the multiple devastating flood events and droughts in Thailand have drawn attention to the importance of understanding long-term climate dynamics of the region. However, the spatial and temporal pattern of monsoon variability and its impact on land cover in Southeast Asia are still unresolved. This shortcoming stems from the fact that temporally well-resolved paleoenvironmental studies are missing for large parts of Mainland Southeast Asia. This research project aims to develop a high-resolution paleoenvironmental/paleohydroclimatic data based on stalagmites derived from Thailand. Given that global and regional climate models increasingly use terrestrial paleodata to test their performance, past hydroclimatic changes record in stalagmites are important variables to better understand feedbacks of Asian summer monsoon. Southern Thailand's limestone bedrock and karst formations make it an ideal target for stalagmites study in this project. Here we combine a new hydroclimate record from southern Thailand west coast, to highlight instant responses of Indian Ocean summer monsoon to high-latitude northern Atlantic since the last 16 Kyrs. Although the onset and termination are synchronous across the records, the Atlantic temperature records clearly show that the Younger Dryas was an abrupt climate change event during the last deglaciation. Current publication suggests no direct evidence of boreal summer monsoon changes in the Western tropical Pacific to date (Partin et al., 2015). The new hydroclimate record from southern Thailand suggests that Mainland Southeast Asia may reflect isotopic changes in precipitation over India via atmospheric moisture transport indicating a reduction in the boreal summer monsoon.

2k climate variability: the central western Mediterranean from speleothems and marine sediments

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Here we present atmospheric and surface-deep ocean interactions reconstruction for the last 2.7 kyr in the central western Mediterranean taking the advantage of the high sensibility of this region to climate variability.
Atmospheric conditions have been evaluated after speleothem records from a Mallorca-Cave and, ocean-conditions in base to sediment multicores from the North Minorca drift. Instrumental measurements of deep-sea currents from moorings have also been evaluated. Hydrological fluctuations on land are interpreted from stable isotopes and trace elements records from four U-Th dated speleothems. Sea surface temperatures (SST) are derived from Mg/Ca-Globigerina bulloides-ratios (Cisneros et al., 2016). Deep-current intensity-changes associated to the main core of the Western Mediterranean Deep Water (WMDW) are evaluated by means of grain-size analysis (UP10-fraction). The strongest WMDW flow occurred during warm intervals as the Roman Period, but also took place during colder intervals like the Little Ice Age. This observation suggests different triggers for the WMDW-convection. On land hydrology, SST and deep-water fluctuations present a significant centennial-scale variability coupling in the study area. However, atmospheric and ocean conditions do not present a simple-connection. Warmest conditions dominated mostly during the Roman Period and part of the Medieval Climate Anomaly but, according to the speleothem records, wet/dry conditions dominated on land and, deep convection patterns were also very different between these two periods. The comparison between our WMDW-record and other convection record from the Levantine Basin in the Eastern Mediterranean also supports distinct climatic forcings. Taking into account available reconstructions of different modes of climate variability such the NAO and other Mediterranean and North Atlantic climate records, the climate variability in the region was most likely caused by a combination of distinct climate modes that should have occurred during the last 2.7 kyr.

Sea-surface temperatures during Dansgaard-Oeschger events 5-8, a model-data integration study

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Proxy data suggests a large variability in the North Atlantic sea-surface temperatures (SST) during the Dansgaard-Oeschger (DO) events of the last glacial. However, as the SST records are limited by suitable sites for marine sediment cores, a full-spatial picture of the SSTs can't be obtained with proxy data alone. Here, we combine fully coupled, general circulation models (GCM) with SST reconstructions using planktonic foraminifera to attain a broader spatial picture of the ocean state during DO events 5-8. GCM simulations are treated as a pool of possible ocean states from which the closest match to the observations is selected based on an objective cost function. The original chronology of the model is replaced by that of the proxy data. Repeating this algorithm for each proxy time step yields a comprehensive four-dimensional dataset that is consistent with reconstructed data. In addition, the solution also includes variables for which no reconstructions exist.
Based on our analysis, we show that a pre-industrial control climate is enough to explain the frequency of the variability seen during glacial times, suggesting that parts of the DO events can be explained by internal variability of the climate system alone. To capture the full amplitude of the oceanic DO variations, GCM simulations with glacial boundary conditions seem to be needed. Results include a dipole pattern between the SSTs north and south of the Greenland-Scotland Ridge and a strong SST signal in the subpolar gyre. We study the robustness of the results to uncertainties in the original age models of the proxy data and to the number of available temperature reconstructions.
This work originated from a PhD-led workshop where we aimed to improve the interaction between data- and model-based PhD students.

Linking explosive 19th century volcanoes with wild storms over southernmost Africa: a case of cause

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The importance of historical weather observations and associated data rescue has gained recognition in recent years, particularly in the context of improving the quantification of recent long-term climate trends, fluctuations and extremes. To this end, our study uses one of the longest continuous instrumental weather records available in the southern hemisphere (Royal Astronomical Observatory, Cape of Good Hope, South Africa: 1834-2016) to establish dynamical linkages between climate forcings/anomalies (e.g. volcanic eruptions, solar variance, ENSO events) and ground-based weather (synoptic) responses, with a specific focus on the 19th century. The presentation focuses specifically on the likely extent to which volcanic eruptions and El Niño events (operating in isolation or in combination) may have separately or collectively impacted upon observed weather/climate at the Cape of Good Hope also known as the Cape of Storms. Work entailed a two-year digitisation (from original archived hard copy Meteorological Registers) and data quality/cleaning processes, followed by statistical analysis of daily data including: barometric pressure; wind direction and speed; air temperatures and rainfall. Tentative results indicate significant positive departures in wind velocity at the Cape of Good Hope immediately (within a few weeks) following major volcanic eruptions (Coseguina (1835), Amargura (1846), Cotopaxi (1855) and Makjan (1861). Such positive wind velocity anomalies are particularly apparent during summer months, while lower mean barometric pressure may suggest enhanced northward displacement of mid-latitude cyclones from the Southern Oceans during months following such eruptions overall, providing for increased [wind] storminess. It would seem that in most instances, major 19th century volcanic eruptions were followed by El Niño conditions (possibly inducing or strengthening El Niño events), yet the most pronounced (extreme) climate departures occur soon after major eruptions, rather than when only influenced by El Niño.

YSM 2 - Biosphere and ecosystem dynamics

Diatom biogeography in tropical South America: importance of climatic and spatial factors

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A reigning hypothesis is that microorganisms, given their highly efficient dispersal, lack biogeographic patterns and are ubiquitous. This hypothesis implies that microbial communities are constrained by local (environmental) factors rather than regional and broad-scale factors, such as such as climate or spatial conditions, or a combination of both. However, an increasing body of research suggests that microorganisms, such as diatoms (unicellular siliceous algae), have distinctive biogeographic patterns with no clear evidence for ubiquitous global distributions. This evidence comes from mid- and high-latitude regions, with limited data from tropical South America, considered a mega diverse region. As part of a multidisciplinary project on the interaction of climate and geology in influencing patterns of biodiversity in the Neotropics, we are analyzing the distribution and diversity of diatom assemblages across >180 lentic and lotic environments of the tropical Andes and Amazon lowlands (0-28ºS and 58-80ºW). Given the sharp contrasts in climatic and

landscape conditions, we postulate that diatoms will show significant spatial structure in their communities and species pool, constrained by historical factors (i.e. dispersal limitation, immigration, colonization-extinction). Diatom assemblages and climatic, landscape and spatial predictors have been related at two different levels: i) species composition (presence-absence) and ii) diversity. Initial results indicate that landscape configuration (density of lakes, habitat connectivity, and lake size) and climatic conditions were most significant in structuring diatom assemblages. Variation partitioning reveals that these same predictors (climatic and landscape) outperformed local variables. Diatom diversity was negatively correlated with seasonality in temperature and precipitation, whereas lake size and habitat connectivity had a positive effect. Our results seem to be consistent with the hypothesis that diatoms exhibit biogeographic patterns and suggest mechanisms for the relatively high provinciality and endemics reported in diatom flora of tropical South America.

The relationship between extratropical plant diversity and Pleistocene climate stability

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It's often assumed that biodiversity decreases with a more or less constant gradient from the tropics towards polar latitudes. Ecological hypotheses attempting to explain this pattern often depend on the occurrence of high temperatures in the tropics to explain high levels of diversity[1,2]. However, Mediterranean Climate Ecosystems (MCEs) are notable for their high plant biodiversity despite their characteristic cool winter rainfall climates. Remarkably, some MCEs, especially the Cape Floristic Region (CFR), even exceed the species numbers per area of continental tropical biodiversity hotspots[3].
An alternative hypothesis to explain the high diversity in these regions is that climatic and topographic stability lead to low rates of extinction of older taxa, while constant rates of speciation allow for the accumulation of new species[4].
Climatic variations that would affect vegetation, such as changes in temperature, rainfall amount and soil processes related to water availability, as well as vegetation changes themselves, are recorded in the stable isotopic composition of speleothems.
We present the first record of speleothem stable isotopic compositions that covers ~300 ka in the Pleistocene from the western part of the CFR. Comparing the amplitude of the stable isotopic records to those from other MCEs, and from the eastern section of the CFR, shows that climatic conditions in the western CFR were more stable than they were in the other regions. This is therefore the first long paleoclimatic proxy record confirming climatic stability in this exceptionally diverse region.

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Impact of mid-Holocene drought upon Bolivian seasonally-dry tropical forests

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Dry forests are the most threatened tropical forest type in South America, with higher rates of deforestation and fragmentation than humid rainforests. The Chiquitano dry forest is the largest block of intact seasonally-dry tropical forest in South America and is a priority ecoregion for conservation. Understanding how resilient these forests will be to future climate-change-induced drought in the region is critical to conservation efforts.
This study uses a palaeo-ecological approach to improve understanding of the long-term impact of drier climatic conditions on the Chiquitano dry forest. This enables investigation of forest sensitivity/resilience over centennial-millennial timescales. The mid-Holocene drier period, ~6000ya, is used as an imperfect analogue for future climate-change-induced drought in the region.

I present some of the findings of my PhD work including pollen data from a lake sediment record from eastern lowland Bolivia. The vegetation record shows significant changes in forest composition during the mid-Holocene drier period, with increases in abundance of several indicators of more open, savannah-like systems such as Borreria (Rubiaceae), Alternanthera (Amarnathaceae) and Curatella Americana (Dilleniaceae). However dry forest indicators, Anadenanthera (Fabaceae) and Astronium (Anacardiaceae), are also present at this time. This suggests that dry forest was not resilient, as a biome, to drier-than-present climatic conditions as previous work in the region had suggested. This has serious implications for future conservation of this biome under climate change induced drought scenarios. Phytolith, charcoal and δ13Csediment data from this site will also be presented, providing a detailed reconstruction of this biome's vegetation and fire dynamics under drought.

YSM 3 - Human-climate-ecosystem dynamics

Contributions to Pliocene Arctic warmth from a clean atmosphere and enhanced forest fire emissions

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Changing atmosphere chemistry in the past has been hypothesized to have altered the earth' s radiation budget, and hence the climate. Here, we use an advanced climate model to test whether this hypothesis can help explain the amplified warming in the northern high latitudes during the mid-Pliocene warm period (mPWP, 3.0-3.3 Ma). This amplified warming, suggested by terrestrial proxy records of the northern high latitudes, is underestimated by previous climate simulations. This model-proxy data mismatch may be partially attributable to proxy uncertainties, but also to insufficient model sensitivity, or incomplete knowledge of mPWP climate forcings.

To explore the latter aspect, we conduct three coupled simulations using the same mPWP geography and topography, vegetation and CO2 level according to the PRISM3 reconstructions, but alternating emission

scenarios among clean, polluted, and clean plus forest fire case. In the clean and polluted case, year-1850 emission and year-1850 natural plus year-2000 industrial emission are prescribed respectively. For the clean-plus-forest fire case, emissions from mPWP forest fire are estimated with a process-based prognostic fire model using fixed mPWP proxy SSTs. Preliminary results suggest that mPWP Arctic warmth is largely attributable to the removal of anthropogenic aerosols and enhanced deposition of black carbon emitted from northern high latitude forest fires on snow and ice. Cloud radiative responses are shown to accelerate the summer sea ice melting from the continental margins, triggering the positive surface albedo and water vapor feedback that maintain a low perennial sea ice state in the Arctic Ocean. These results identify the important role that changes in aerosol chemistry may play in amplifying the mPWP and potentially future surface warming of the Arctic region.

Distinguishing Amazonian climate versus human driven fire regimes since the Last Glacial Period

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There is currently a debate over the extent of pre-Columbian impact on Amazonia ecosystems, ranging from near pristine to intensely humanized ecosystems. To explore long-term drivers of fire and vegetation change, a 50,000 year old sediment core record from Laguna Chaplin was analyzed to develop a paleoecological toolkit to detect pre-Columbian human disturbance in the Bolivian Amazon. A modified pollen sieving method was used to concentrate potential crop pollen as an indicator for past human occupation. High-resolution sampling of macrocharcoal was analyzed using statistical algorithm software including CHAR Analysis and Regime Shift Detection to identify changes in past fire regimes on local and regional scales. Over the past 50,000 years climate, particularly changes in precipitation, was the dominant driver of fire activity and biomass burning at Laguna Chaplin. From ca. 46,000-2,000 cal yr BP pollen data indicate vegetation was dominated by fire adapted seasonally dry forest/savanna swamps. There was a shift towards less flammable, non-fire adapted rainforest vegetation after ca. 2000 cal yr BP. At ca. 1,000 cal yr BP, increased fire frequency became antiphased with local and regional decreases in biomass burning. During this period the presence of poorly dispersed domestic corn pollen (Zea mays) indicated that agriculture was practiced around Laguna Chaplin. These data suggest pre-Columbian forest and fire management practices were occurring since the last millennium. Frequent low intensity human caused fires were likely used to ameliorate the nutrient poor tropical soils to benefit agricultural crop yields. Thus climate was the ultimate driver of late Holocene forest expansion and decreased local and regional biomass burning despite local forest and fire management around Laguna Chaplin. This study demonstrates the benefits of applying a multi proxy, high-resolution paleoecological toolkit in the detection of pre-Columbian occupation and to distinguish climate and human drivers of past ecological change in the Amazon.

Relative impact of climate change and human activities on the ecosystems in southwest Madagascar

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Madagascar is commonly regarded as a biodiversity hotspot that is primarily impacted by human activities. However, climate variation, especially the reduction of rainfall has been considered as a potential key driver impacting species composition in the Southwest of the island. Some of the legacy of past climate change , but also current climatic factors is the vegetation distribution gradient from dry to spiny forest. Few studies have investigated the impact of rainfall variability on vegetation composition and structure. A long-term study using sedimentary and dendroclimatological records may facilitate the understanding of the patterns of environmental change in the

last 2000 years in response to regional rainfall variability. Preliminary results obtained from the Carbone isotope content of baobab demonstrated millennium to decadal variation of the regional rainfall. During the next six months, I will be finalizing my rainfall records and count pollen content of my sediments samples to reconstruct vegetation change. The presentation will discuss the vegetation, climatic gradients, human impact and land_use change in Southwestern Madagascar. This study has implications in the prediction of future scenarios in rainfall variability and vegetation changes to enable stakeholders and conservationists to develop better adaptive strategies reconciling sociological and conservation aspects within this unique biodiversity hotspot.

Late Pliocene East African climate variability reconstructed from the Baringo Basin (Kenya) HSPDP Drilling Project

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Outcrops in the Kenyan and Ethiopian rift valleys document repeated occurrences of freshwater lakes and wooded landscapes over the past 4 million years. Studies of fossil hominin sites associated with the lacustrine sequences are providing novel perspectives on driving factors in human evolution. In addition, the continuous drill cores from ancient lake basins provides a high resolution framework for reconstructing East African climate dynamics that can build on models based on outcrop analyses.

The Hominin Sites and Paleolakes Drilling Project (HSPDP), and the related Olorgesailie Drilling Project, has recovered ~2 km of drill core from the East African Rift Valley since 2012. A major project goal is characterization of East African paleoclimate in order to evaluate its impact on hominin evolution. XRF core scanning data provide a means of evaluating records of past environmental conditions continuously and at high resolution. The HSPDP records contain complex lithologies reflecting repeated episodes of inundation and desiccation of the lake basins. Careful data evaluation based on detailed lithostratigraphy, which includes smear-slide microscopic analyses and X-radiographic images, allows disentanglement of complex signals and robust identification of continuous sequences for any cyclostratigraphic and statistical analysis.

At the HSPDP Baringo Basin (BTB) site, a 230m core in the central Kenyan Rift, spans the Late Pliocene and samples a portion of the Chemeron Formation in the Tugen Hills Succession. The Chemeron Formation documents repeated cycling of major freshwater lake systems at 23 ka precessional pacing, occurring at the maximum of an Earth orbital eccentricity cycle. Over 30 vertebrate fossil localities, including hominins, can be linked to the sequence. Ongoing research of the new drill core show repeated appreance of diatomites reflected as cyclic repetitions of increasing and decreasing Si/Ti XRF ratios. With the the XRF data, we present a methodological approach to address the highly variable lithostratigraphy of the East African records to establish comprehensive and environmentally meaningful paleoclimate timeseries. Furthermore, the reconstructed hydroclimate variability of the Baringo Basin from 2.6 to 3.3 myrs is explored in relation to regional reconstructions and marine stratigraphies. These data will provide a chance to link evolutionary innovations in the human lineage with environmental changes in the rift valley.

YSM 4 - Abrupt changes and threshold responses

Holocene Activity of the Petermann Glacial System

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Large calving events of the Petermann Ice Tongue, Northwest Greenland, in 2010 and 2012 seem unprecedented in the context of the limited historic record, dating back to the 1875-1876 British Arctic Expedition led by Sir Nares, and more recent satellite observations of the last two decades. Modern studies demonstrate that this marine terminating sector of the Greenland Ice Sheet is especially sensitive to oceanic forcing, but paleo data are required to provide a more holistic context of these changes. We present a suite of analyses on sediment cores collected during the international and interdisciplinary 2015 expedition to Nares Strait and Petermann Fjord onboard the Swedish Icebreaker Oden, documenting new perspectives of the early Holocene deglaciation of Nares Strait and a new high

resolution record of mid to late Holocene dynamics of the Petermann glacial system. CT scans allow for clear identification of a number of glaciomarine depositional environments and for high resolution quantification of >2 mm clasts. The distinct local carbonate bedrock surrounding Petermann Fjord and crystalline basement rocks excavated by the inland Greenland Ice Sheet are tracked using Q-mode factor analysis of scanning XRF data, displaying strong gradients in sediment composition between the Ca-rich sediments proximal to tidewater glaciers of the local ice cap and sediments proximal to the grounding-line of Petermann Glacier. Paleomagnetic measurements isolate a strong and stable characteristic magnetization, which show remarkable similarilty to Paleosecular Variation (PSV) recorded in nearby mid to late Holocene varved lakes on Ellesmere Island. Together, this non-destructive dataset provides robust correlations, indicating a coherent and dynamic record of changes in the Petermann glacial system during the late Holocene, including evidence for at least two significant grounding-line retreats followed by the late Holocene growth and relative paleo-extent of the modern Petermann Ice Tongue observed by Sir Nares.

Abrupt ecological transition in China's aquatic systems during the last two centuries

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Dealing with grant challenges of Anthropocene needs rigorous understanding of linked social-ecological system, which are complex, adaptive system characterized by historical dependency, nonlinear dynamics and uncertainty. Examining regime shifts occurred in the past could offer rich opportunities to increase understanding of patterns and process of governing regime shift, and impact on ecosystem services and society. China's unprecedented environment degradation under social-economic transition provide a unique case to explore how ecological system changed in the Anthropocene, which could not only increase new understanding of ecosystem regime shift, but also generate valuable information for environment restoration and management, not only for China, but also for other developing countries facing similar challenges.

Here, we synthesis and examine paleoecological records across multiple trophic levels, in 20 different typical aquatic ecosystems in China that include shallow lakes, deep lake and coastal marine ecosystems. Comprehensive tests of nonlinear change across species, community and ecosystem types during the past 200 years were undertaken by employing multiple statistic approaches. Significant ecological nonlinear transition were identified at regional scale during 1960-1980s. However, close examination indicate that these ecological nonlinear change show different temporal and spatial patterns. We also find time-lag between different community shifts and ecosystem level shift. These spatial and temporal heterogeneities argue against a synchronous regime shift of ecological community from one well-defined regime to another. Accumulating drivers interact with each other reduce system resilience, and finally leading to critical transition. A combination of empirical, modeling, and theoretical approaches is required to better understand how ecological system shift are caused by social transition.

YSM 5 - Modeling

Disequilibrium DIC: Carbon storage and the effects of ocean circulation and the soft tissue pump

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The ocean is believed to play an important role in the drawdown of atmospheric carbon dioxide during glacial periods. Within this reservoir, dissolved inorganic carbon can be divided into a preformed and remineralized, or biological, component. The preformed DIC, DIC(pre), is set in the surface ocean primarily by air-sea gas exchange (saturation DIC). However, because of the long timescale of air-sea exchange for carbon, DIC(pre) also includes a disequilibrium component, DIC(dis). DIC(dis) is very small over most of the ocean, but can be quite large in polar oceans, particularly the Southern Ocean. Due to glacial-interglacial variations in the efficiency of carbon drawdown due to the soft tissue pump and upwelling related to ocean circulation as well as gas exchange associated with sea ice, DIC(dis) in this region could potentially change significantly on these timescales.

Here, we present results from steady-state simulations using a coupled general circulation model to explore the impacts of

orbital forcing, ice sheets, CO2 and iron fertilization on DIC(dis) through their impacts on ocean circulation, sea ice and the marine biological soft tissue pump. The simulations show that the magnitude of DIC(dis) varies on the order of several 10s of µmol/kg, which could have exerted a significant impact on atmospheric CO2 on glacial-interglacial timescales. Relationships between DIC(dis), soft tissue pump carbon storage and ocean circulation will be discussed.

The large scale responses of water isotopes to changes in Earth's orbit

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Orbital variability is a dominant driver of climate change on long timescales. Within the Quaternary, orbital forcing influences glacial cycles, monsoon intensity, and large-scale dynamic oscillation. Our interpretation of the paleoclimate responses to orbital change is based, in large part, on water isotopic records. However, analyses of the signals within these isotopic records are often simplistic. To better understand the orbital signals found within water isotopic records of the Quaternary, we use the Community Earth System Model with a newly implemented water isotope tracking component. We perform a series of idealized orbital experiments within a fully coupled Earth System framework that includes interactive atmosphere, ocean, land, sea ice, and runoff components. These simulations allow us to improve our understanding of the climate dynamics that led to key isotopic variability within the Pleistocene and will serve as a tool for interpreting new isotopic records.
Our preliminary results suggest that orbital variability has a strong control on regional isotopic distributions, which are not deducible from local temperature and precipitation changes alone. This divergence is due, in part, to circulation changes in features such as the El Nino Southern Oscillation and Atlantic Meridional Overturning Circulation with variations in obliquity and precession/eccentricity. Further, the deep ocean response, especially in the Atlantic, is larger for variations in obliquity than precession, which may have implications for our interpretation deep-sea sediment cores and the glacial cycles of the Pleistocene.

Influence of CO2, the Antarctic Ice Sheet and Asian Topography on the Asian Monsoon and Regional Moisture Availability

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Asia is the most densely populated continent on Earth and has a varied climate with environmental conditions in East and South Asia dominated by the monsoons, whilst central Asia is characterized as arid. Studies examining the onset of aridity and the intensification of the monsoons controlling Asian climate have generated significant debate. Researchers have identified the major drivers of Asian aridity being the Himalayan and Tibetan Plateau uplift, the retreat of the Paratethys Sea, and the global cooling after the Eocene/Oligocene transition. Here, using results derived from 7 climate simulations of a fully coupled ocean-atmosphere climate model (HadCM3L), we investigate the effect of Antarctic ice-sheet formation, CO2 decline and Himalayan elevation changes on the moisture supply in inland Asia and on the Asian monsoon circulation. Overall simulated precipitation changes in Central Asia are modest, with the most pronounced response being confined in the regions associated with the South Asian Monsoon and East Asian Monsoon. However, changes in Himalayan elevation alter the flow of the westerlies, which are considered to be the main moisture source for inland Asia. With no Antarctic ice Sheet the westerlies are strengthened and displaced northward. Decreasing atmospheric CO2 concentration displaces the position of the Intertropical Convergence Zone to the south. Overall, these result indicate a complex interplay of forcings and climate responses driving regional changes in hydrology over the last 33 million years.

YSM 6 - New technical and methodological development in past global changes

A novel framework to optimise palaeoclimatic information derived from fossil pollen data

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Quantifications of past climate have thrived in the past decades. Unfortunately, this accumulation of data has not necessarily been followed by has much progress as was initially expected. We argue that this can be partly explained by the usual poor considerations given to uncertainties, as most reconstructions are commonly presented and interpreted according to the likeliest scenario only, a scenario defined by associating one age and one climate value to each sample. In this paper, we present a new framework that creates and fully integrates temporal and climatic uncertainties and uses them as a reliable source of information to derive robust palaeo-reconstructions. Temporal uncertainties are obtained from the Bayesian age-depth modelling technique Bacon, and the climate uncertainties from the reconstruction method CREST (Climate REconstruction

SofTware) we have recently developed. CREST is based on probability density functions (pdfs) and its approach guarantees that the full range of possibilities are conserved at each step of the process, as uncertainties are never reduced to any single parameter. CREST and Bacon have the strong advantage of providing posterior distribution of climatic and temporal probabilities, respectively, for each of the samples. Our framework is built on the use of those uncertainties. Instead of reducing them to a likeliest value (e.g. estimated from the optimum of the distribution curve), it rather focuses on combining and integrating all the potentialities within a Monte-Carlo process that ameliorates the signal over noise ratio of the record by sampling hundreds of thousands scenarios. The full spectrum of these randomly generated scenarios results in an optimised picture of past climatic and/or environmental conditions, a picture that is by far more accurate than the most simple likeliest scenario. The framework will be illustrated with a case study performed across southern Africa.

A terrestrial Pliocene-Pleistocene temperature record from North-Western Europe

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The Mid-Pliocene Warm Period (MPWP) (ca 3.3 to 3.0 Ma) is the most recent geological interval that serves as an appropriate analogue to our current climate, due to similar atmospheric CO2 levels (400–450 ppmv) and comparable continental configurations. The MPWP is especially interesting regarding future climate predictions as global temperatures were roughly 2-3 °C warmer than present, indicating that current climate may not yet be in equilibrium. Reconstructions of MPWP sea surface temperatures (SSTs) indicate SSTs were warmer than present, particularly at high latitudes (ΔSST = 2-6 °C). However, continental temperatures for this interval remain poorly constrained due to a lack of trustworthy proxies, and scarcity of terrestrial sedimentary archives. Here we analysed branched GDGTs (brGDGTs) in a coastal sediment core from the Netherlands to reconstruct continental mean air temperatures (MAT) in North-Western Europe during the Early Pliocene to mid-Pleistocene. BrGDGTs are membrane lipids of organisms living predominantly in soils whose relative distributions relate with the temperature and pH of the soil in which they are biosynthesized. BrGDGTs can be delivered to coastal marine sediments by fluvially transported soil material. Our MAT record indicates that temperatures on the EU continent were 2-3 °C higher during the MPWP than today, and also reflects onset of Northern Hemisphere glaciation by unstable and fluctuating temperatures. Interestingly, in addition to the M2 glacial event, the record shows the occurrence of another potential glaciation around ~4.9 Ma, and is supported by the palynological record based on pollen and dinosyst assemblages. Moreover, the coastal position of the sample site enables the evaluation of land-sea climate interaction by the parallel application of marine lipid temperature proxies (i.e. Uk37, TEX86, and long chain diol index (LDI)) on the same core, thus providing crucial input data for earth system models.

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