The North Atlantic Current (NAC) brings warm and saline water into the Arctic: this inflow is balanced by the outflow of cold surface water and by the formation of deep water to the south, which is part of the Atlantic Meridional Overturning Circulation (AMOC). Changes of the AMOC can greatly affect the global ocean circulation and climate, especially at high latitudes where the inflow of warm water, heat exchange and its effect on sea ice formation is essential for environment and society. Hence, it is crucial to establish the natural range of oceanographic fluctuations within this area. Here we investigate a continuous high resolution record from the Kveithola Throug, western Barents Sea, in order to elucidate the past variability of the Atlantic Water flow and sea ice distribution throughout the Holocene.

The age model is based on nine AMS C¹⁴ dates, and shows sediment accumulation rates up to 0.034 mm/yr, enabling a sub-centennial resolution. Planktic foraminifera and stable isotopes were analysed. In addition, the sea ice biomarker IP₂₅ is measured in order to establish a reconstruction of temporal changes in sea ice cover. Finally, Mg/Ca ratios will be presented in order to further quantify the surface water mass properties as SST and SSS.

The planktic foraminiferal stable isotopes show warming at ca. 10 000 cal yr BP followed by a cooling from ca. 8 000 cal yr BP until present day conditions. This long-term cooling correlates to the decreasing June insolation at 70° N following the orbital forcing. The planktic foraminiferal fauna has two dominating species: the polar N. pachyderma (sin) and the sub-polar T. quinqueloba. The early Holocene is dominated by N. pachyderma (sin), while throughout the mid and late Holocene T. quinqueloba dominates the fauna with values up to 75% possibly reflecting a high nutrient availability close the sea ice margin. The sea ice indicator IP₂₅ shows that the core site is influenced by sea ice in the early Holocene. From ca. 8 500 to 2 500 cal yr BP the sea ice gradually decreases. After this time the IP₂₅ record increases suggest a returned appearance of sea ice although in a smaller extent than during the early Holocene.
In this study, we examine the state of the Atlantic thermohaline circulation at the end of the last interglacial (129ka to 116 ka). More specifically, we consider the effect of tropical precipitation changes on modulating the salinity of the North Atlantic, and the persistence of the thermohaline circulation during the formation of continental Northern Hemisphere ice sheets. We utilize a combination of tropical precipitation reconstructions and modeling scenarios to investigate the teleconnection between the tropics and North Atlantic. The tropical rainfall records derive from marine sediment core transects from the South American and African margins in the tropical Atlantic. The rainfall reconstructions are translated into forcing fields for general circulation model experiments using the Community Climate System Model (CCSM). In this study, we report the results of two primary sets of model experiments. In the first we compare paleoclimate simulations of the last interglacial using CCSM to the sediment core based reconstructions. Second, we report the results of an ensemble of sensitivity experiments in which we investigate the role of modeled and reconstructed tropical precipitation changes on the North Atlantic salinity and deep water formation. More specifically, we report how modifications to the precipitation the ocean receives in the tropics propagate to the North Atlantic and in turn impact the deep water formation. The work will continue with an investigation of the role a persistent thermohaline circulation has on the formation of Northern Hemisphere ice sheets.
Location of the Marine ITCZ in the Atlantic Ocean over the last 30 ka

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The Atlantic Intertropical Convergence Zone (ITCZ) is a major atmospheric feature of the tropical ocean driving wet and dry seasons for many countries in South America and Africa. Understanding past shift of the mean position of the ITCZ in response to high latitude conditions and isolation forcings is crucial to forecast future climate in a shrinking polar ice world. A number of terrestrial and coastal records have already shown large displacements of the ITCZ with changing climate but these records bear the influence of land-driven ITCZ displacement. Over continental areas seasonal displacements of the ITCZ are very large, on the contrary, the ITCZ over the Ocean has a much reduce seasonal shift, its mean position in the Atlantic Ocean is located at 5˚N. In this work, we reconstructed the location of the marine ITCZ in the Atlantic Ocean and study its variability over the last 30 ka. We used a series of 15 sediment cores located along the mid-Atlantic from 26˚N to 17˚S. We measured the stable oxygen isotope and Mg/Ca composition of the foraminifer G. ruber and calculated thermal and salinity gradients change at millennial resolution over the transect. Our reconstruction shows large changes of the salinity minimum and temperature maximum bands both in their latitudinal positions and intensities.
The eastern South Pacific is characterized today by a complex thermocline structure where large salinity and oxygen changes as a function of depth coexist. Surface waters from tropical origin float on top of subantarctic fresher water (the so-called ‘shallow salinity minimum of the eastern south Pacific’), which in turn, flow above low oxygen and high nutrient equatorial subsurface waters and deeper, recently ventilated Antarctic Intermediate waters. Little is known however about the water mass geometry changes that could have occurred during the last glacial maximum boundary conditions (about 20,000 years before the present), despite this information being critical for the assessment of potential mechanisms that have been proposed as explanations for the deglacial onset of low oxygen conditions in the area and the atmospheric CO$_2$ increase during the same time.

Here we present benthic and planktonic foraminifera stable isotope and radiocarbon data from a set of sediment cores from the Chilean continental margin covering a large -yet still limited- geographical area and depth range. Sedimentation rates were relatively high (>10 cm/kyr) precluding major caveats from bioturbation in all of our archives. The distribution of $\delta^{13}C$ of $\Sigma CO_2$ shows the presence of a very depleted ($\delta^{13}C < -1\%$ V-PDB) water mass overlaying more recently ventilated waters at intermediate depths as indicated by thermocline foraminifer dwellers being more depleted in $^{13}C$ than the benthic species. The origin of this depleted end-member is probably upwelling from the Southern Ocean as expressed by the radiocarbon content and the large reservoir effect associated with the last glacial maximum and the beginning of the deglaciation along the margin. Our data suggest that the Tropical waters that today bathe the lower latitude cores was displaced by surface waters of southern origin and therefore in line with the evidence of a latitudinal shift of the frontal systems.
Reconstructing Plio-Pleistocene Intermediate Water Temperatures Using Mg/Ca of Infaunal Foraminifera (*Uvigerina peregrina*)

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The reconstruction of past surface, intermediate and deep-water temperatures is critical for our understanding of feedbacks within the ocean-climate system. Proxies for determining the paleotemperature of interior water masses have many caveats including the ‘Carbonate Ion Effect’ on the Magnesium to Calcium ratio (Mg/Ca) of benthic foraminifera. Recent studies have demonstrated that the shallow-infaunal species, *Uvigerina peregrina*, co-precipitates Mg independent of carbonate saturation state, affording the use of Mg/Ca_Uvigerina for Quaternary paleotemperature reconstructions (Elderfield et al., 2010).

Herein, we present the first record of intermediate water temperatures for critical time-periods during the Pliocene and Pleistocene, including the Mid-Pleistocene Transition (MPT), from a sediment core in the Southwest Pacific (DSDP site 593; 40°30'S, 167°41'E, 1068m water depth), within the core of modern Antarctic Intermediate Water (AAIW). By comparing Mg/Ca_Uvigerina, Mg/Ca_Cibicidoides, and δ¹⁸O_Cibicidoides, a multi-proxy approach helps to further demonstrate the utility of Mg/Ca_Uvigerina as a paleotemperature proxy, without effects of carbonate ion. We then examine the changing structure of the interior Southern Ocean through the Plio-Pleistocene by comparing our new intermediate-water paleotemperature estimates with sea surface paleotemperature estimates generated using the alkenone-derived U₃⁷ index from the same site, as well as deep-water paleotemperature estimates from a proximal site, ODP site 1123 (3290m water depth; Elderfield et al., 2010; 2012). Intermediate water temperature reconstruction is particularly important since intermediate waters, including AAIW, are proposed to be a main driver in high-low latitude teleconnections. However, quantitative information about how intermediate waters evolved through the Plio-Pleistocene remains scarce.

The production strength and depth of intermediate water formation in the Southern Ocean is directly tied to the location of the Sub-Antarctic Front (SAF). DSDP site 593 lies just north of the modern SAF, and its location is presumed to oscillate between north and south of the front according to the orbitally-timed latitudinal migration of the SAF (Sikes et al., 2009). Consideration of changes to the SAF is made possible through comparison of Southwest Pacific sea surface temperature record with a high-resolution sea surface temperature record from the South Atlantic (ODP site 1087; 31°28'S, 15°19'E, 1374m water depth), which also lies just north of the modern SAF.
Poster
Holocene Atlantic bottom water inflow at the western Barents Sea margin, European Arctic

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The northward flow of warm and saline Atlantic Water forms an integral part of the Atlantic meridional overturning circulation (AMOC). Variability in the AMOC can affect the convective formation of deep water in the Nordic Seas and thereby the global ocean circulation. Additionally, variations in the inflow of Atlantic Water govern the ecological conditions at higher latitudes. Hence, it is crucial to establish the natural range of oceanographic fluctuations. Here we investigate a high resolution record from the western Barents Sea margin to elucidate any changes in the flow of Atlantic Water into the Arctic Ocean during the Holocene. Benthic foraminiferal assemblages and δ¹⁸O values (Cassidulina neoteretis) indicate rapid bottom water warming at the start of the Holocene with a replacement of the cold water species E. excavatum f. clavata by species such as C. neoteretis and Cassidulina reniforme, associated with cooled Atlantic Water. From ca. ± 10,000 to 2,000 cal. yr. BP. the foraminiferal assemblage indicates stable conditions while the δ¹⁸O record shows a cooling trend that can be correlated with summer insolation at this latitude following orbital forcing. The bottom water properties will furthermore be investigated using Mg/Ca ratios measured on C. neoteretis. Opposite to the stable foraminiferal assemblages, there are two large lithological changes. Around 8000 and 1500 cal. yr. BP. both the grain size and the foraminiferal productivity increase, indicating an increase in bottom current strength and more favorable living conditions. This change probably represents an amplified, regional, inflow of Atlantic Water into the Barents Sea.
Suborbital ice-sheets variability in the subpolar North Atlantic during the Early and Mid-Pleistocene (MIS 31–19) as a response of low-latitude forcing

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A new high-resolution planktonic and benthic δ¹⁸O time series, faunal-based sea surface temperature (SST) reconstructions and ice-rafted debris (IRD) records from the Integrated Ocean Drilling Project (IODP) Site U1314 (56.36°N, 27.88°W), in the subpolar North Atlantic, were examined to investigate orbital and suborbital climate, ocean hydrography and ice-sheet dynamics during the Early and Mid-Pleistocene, from Marine Isotope Stage (MIS) 31 to MIS 19 (1069–779 ka). Benthic and planktonic oxygen isotopes, IRD and SST show a different pattern before and after MIS 25 related to the transition between 41-ka and 100-ka glacial-interglacial cycles which occurred during the Mid-Pleistocene Transition. Beside the glacial-interglacial (G-IG) variability and the large increase in Northern Hemisphere ice-volume, linked to the cyclicity change, we observe a persistent suborbital climate fluctuations, starting with an abrupt warming event that is followed by gradual and progressive cooling to culminate with an event of iceberg discharge at the time of maximum cooling or the ensuing prominent warming. Negative excursions in the benthic δ18O time series observed at the times of IRD events may be related to glacio-eustatic changes due to ice-sheets retreats and/or to changes in deep hydrography. Time series analysis on surface water proxies (IRD, SST and planktonic δ¹⁸O) of the interval between MIS 31 to MIS 26 shows that the timing of these millennial-scale climate changes are related to half-precessional (10-ka) components of the insolation forcing, which are interpreted as cross-equatorial heat transport toward high latitudes during both equinox insolation maxima at the equator. These observations support the hypothesis that during the Early and Mid-Pleistocene, changes in low-latitude insolation forced suborbital climate variability at higher latitudes in the North Atlantic before the establishment of high-amplitude 100-ka glacial cycles from the Late Pleistocene.
Talk
Mid-Holocene amplification of century scale climate variability - potential interhemispheric linkages

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Many high latutude paleoclimatic archives in both Hemispheres document an increase in the amplitude of climate variability and an emergence of stronger century scale (and sometimes longer) variability between approximately 5 and 4 ka. In the North Atlantic/Nordic Seas this change is accompanied by more widespread sea-ice cover, changes in the northward ocean heat flux and related parameters of the meridional overturning circulation. Accompanying these changes are growing glacier size in Scandinavia and the Alps, and a marked shift in wintertime atmospheric circulation over Northern Europe, with stronger influence of northerly winds in the winter season, as derived both from glacier records and lake records. In the Southern hemisphere several records point to marked changes in Southern Ocean frontal movements and dynamics related both to changes in the westerlies and ENSO-related influence of tropical waters at SH mid-latitudes. We here identify the characteristics of this marked shift in Holocene dynamics and explore the emergence and phasing of the changes both between paleoclimatic archives and spatially in terms of their interhemispheric phasing. The question of the degree to which the changes are synchronous or reflect a see-saw pattern between the hemispheres is explored via data analyses and data-model integration utilising output from the PMIP3/CMIP5 model experiments.
Antarctic linkages to the deep water flow variability during the past 95000 years in the Indian sector of the Southern Ocean

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Palaeoceanographic reconstruction based on high-resolution benthic (Cibicidoides wuellerstorfi) stable isotope, mean sortable silt (SS) and magnetic grain size records in a sediment core (SK200/22a) from the Sub-Antarctic regime of the Indian sector of Southern Ocean depict the variations in global influence of Circumpolar Deep Water (CDW) and the southward spreading of the North Atlantic Deep Water (NADW). Interestingly, the marine isotopic stage (MIS) 1 and MIS2 are characterized by near constant variations in SS values, negating any significant changes in the flow during these periods. The MIS 2 - MIS 5 periods were characterized by a general increase in SS value with specific increases at around 91-88 kaBP, 80-78 ka BP, 73-72 kaBP, 56-52 kaBP and between 40-37 kaBP, supporting a strengthening of bottom-current activity that triggered winnowing at these periods. The SS records are supported by the low δ¹³C values of C. wuellerstorfi during the glacials and some parts of MIS3 and MIS 5, confirming older nutrient-rich and poorly ventilated southern sourced deep waters at these periods. The core site is within the influence of ACC-CDW current, where it merges with NADW, apparently restricting the southward transport of northern source deep waters during these periods. The termination I is marked by decrease in flow speed and an increase in the C. wuellerstorfi δ¹³C values. Comparison of SS and C. wuellerstorfi δ¹³C record with the Antarctic ice core records reveal that pulses of reduced bottom water flow of CDW/NADW are synchronous with the Antarctic warming Events (A1-A7). Accordingly, the Antarctic warming events are co-eval with a weaker bottom flow that transported finer magnetic grain size, which seem to be particularly sensitive to fluctuations of the CDW/NADW variations. The decreased flow speed during the Antarctic warm events may be due to the lower production rate of southern-sourced water or reduced density, leading to reduced geostrophic flow. During the cold phases of the Antarctic climate, enhanced southern westerly wind transport caused increased sea-ice export leading to increase in density of southern-sourced water, supporting a direct Antarctic linkage on the past changes in deep flow vigour in the study region.
Talk
Increase proportion of Antarctic Intermediate Water off northern Chile (27°S) in glacial periods over the past million years

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While in the past the variability in the production of North Atlantic Deep Water was seen as the major trigger of rapid ocean circulation and climate change, processes occurring in the tropics as well as at high austral latitudes are now viewed as equally important. In addition, efforts are made towards the understanding of the role of intermediate water-mass changes in the global ocean circulation and climate. Among the intermediate water masses, Antarctic Intermediate Water (AAIW) is of particular importance. Of all its has the largest extension, forming at the Antarctic Convergence Zone and spreading as far north as 20°N. Moreover, AAIW plays an important role in the oceanic sinking of CO₂ and in rapid global-scale oceanic overturning processes. Besides, it provides a link transporting signals resulting from processes occurring at high austral latitudes to the rest of the oceans through the so-called “ocean tunnel”. However, at present, few paleoceanographic reconstructions of the characteristics, strength and variability of intermediate waters on glacial-interglacial time scales exist, partially due to the lack of long, high-resolution sediment sequences at intermediate depths. With this contribution we aim to fill in this gap and increase our knowledge about changes in the distribution of the AAIW.

Here we present benthic stable isotope data from the long sediment core GeoB15016 (56 meters composite depth). GeoB15016 was recovered with the sea floor drill rig MARUM-MeBo at 956 m water depth, off northern Chile (27°29.48′S, 71°07.58′W). The sediments at this site presently are deposited at the lower boundary between AAIW and Pacific Deep Water (PDW), allowing Paleolong-term paleoceanographic reconstructions (orbital to sub-orbital time scales) in an area sensitive to AAIW variability.

The GeoB15016 composite record covers the time interval from 965 to 80 ka. In this interval, the benthic δ¹⁸O and δ¹³C records display orbital modulation. The benthic δ¹³C record reveals a strong influence of PDW during interglacial periods (MIS 25 to 5) at the study site. This is indicated by the overlap in δ¹³C values between our intermediate-deep site and deeper records in both the SE and equatorial Pacific. During glacial periods (MIS 26 to 6) the δ¹³C records diverge, with the Geo15016 intermediate water record displaying higher δ¹³C values. This suggests i) a shift in the mixing ratio between AAIW and PDW, with stronger influence of the more δ¹³C-enriched AAIW during glacial; or ii) changes in the properties of either water mass between glacial to interglacial conditions; or iii) a combination of both. A shift in water-mass mixing ratio could be related to a lowering of the boundary between AAIW and PDW due to global sea level change, but also to an increased production of the glacial equivalent of AAIW. We favour and discuss in our presentation the last option.
Cold-water corals of the West: North Carolina contribute to a North Atlantic basin study

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The climate variability recorded for the last million years – and namely glacial-interglacial cycles – has been linked to reorganisations of the North Atlantic thermohaline circulation and water mass distribution. Recently, aragonite-forming cold-water corals (CWC) have become key archives to unravel intermediate water-mass history. Changes on the CWC distribution through time can reveal important insights into the oceanographic conditions that favour coral growth. Moreover, CWC can be accurately dated by means of mass spectrometric U-series dating, thus providing unique records of ocean circulation for the last \textasciitilde300 kyr.

Previous studies in the northeastern Atlantic observed a glacial-interglacial see-saw pattern of the CWC distribution: abundant coral growth occurred north of 50ºN during interglacial periods (MIS1, 5 and 7); and south of 37ºN during glacial periods (MIS2, 3, 4 and 6). Variations in the strength and flow path of the Mediterranean Outflow Water have been suggested to influence this pattern in the north. Oligotrophic conditions, weak tidal currents and changes in water mass density might have caused the CWC demise during warm climate stages in the Gulf of Cadiz and along the Moroccan margin.

While aiming to study CWC development at a basin-scale and its relation to the North Atlantic climatic cycles, we need to know how CWC distribution changed along the northwestern margin of the Atlantic. Here, we present fifteen ages of the CWC \textit{Lophelia pertusa} sampled from mound structures at 320-500m water depth off Cape Lookout (Blake Plateau) on the North Carolina margin (34ºN). Coral (on-mound) and sediment (off-mound) samples, obtained with box- and piston-corers, were used in this study. Uranium-series dating of fossil coral fragments was conducted using MC-ICPMS technology at LSCE (Gif-sur-Yvette). The chronology of one off-mound sediment core was further investigated through \textit{AMS-}\textsuperscript{14}C dating (on planktonic foraminifera).

Our coral samples revealed interglacial ages, from Late- to Mid-Holocene and early Eemian (present and last interglacial, respectively). Hence, we found first evidence that CWC grew during interglacials in the temperate West Atlantic; while in the temperate East Atlantic little CWC development was reported during these warm periods. The temporal distribution of CWC off North Carolina resembles the pattern found much further north in the Eastern Atlantic. It is likely that the Gulf Stream glacial-interglacial cyclicity is somehow related to CWC development in the North Carolina margin.
Stability of the thermohaline circulation during MIS3 in a comprehensive climate model: Towards a dynamical understanding of Dansgaard-Oeschger events

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Marine Isotope Stage 3 (MIS3) was a period of pronounced millennial-scale climate variability, associated with the most regular occurrence of Dansgaard-Oeschger (DO) events. The origin of DO events remains controversial, but there is strong evidence that variations in the strength of the Atlantic meridional overturning circulation (AMOC) were involved. A widely held view of DO dynamics involves switches between two states of different AMOC strength and many conceptual models have been suggested to explain the millennial-scale climate oscillations based on this concept of oceanic bistability. So far, however, no attempts have been made to systematically examine the stability properties of the AMOC in comprehensive coupled climate models under MIS3 boundary conditions. Here, we present results from a series of equilibrium water-hosing experiments using the Community Climate System Model version 3 (CCSM3, including a dynamic vegetation module) forced with MIS3 (38 ka before present) boundary conditions and North Atlantic freshwater perturbations ranging from 0.005 to 0.2 Sv. Without freshwater perturbation, the model simulates an equilibrium North Atlantic overturning-maximum of 17 Sv under MIS3 boundary conditions, which is 3 Sv stronger than in the pre-industrial control run. The southward flow of North Atlantic deepwater occurs at shallower levels in the MIS3 run than under modern conditions. We interpret this configuration as MIS3 interstadial state. This state is remarkably unstable with respect to minor North Atlantic freshwater perturbations, dropping to 10 Sv in response to a weak 0.02 Sv freshwater hosing. The associated reduction in oceanic heat transport leads to a pronounced interhemispheric seesaw pattern in surface temperature with a cooling over central Greenland of approximately 10 K and a warming of 0.5-1.5 K over Antarctica, consistent with the transition to a stadial climate state. For perturbations above 0.02 Sv, the AMOC shows an almost linear response to increasing freshwater forcing. Upon removal of the freshwater perturbation, the AMOC recovers, indicating the absence of multiple equilibrium states. In summary, our hosing experiments reveal a dramatic DO-type global climate shift associated with a non-catastrophic threshold for North Atlantic freshwater perturbations varying between 0.01 and 0.02 Sv. Thus, according to our model results, minor perturbations in the hydrologic cycle (e.g. related to ice-sheet processes) could have triggered substantial global DO climate transitions. Mono-stability of the ocean circulation in the coupled climate model implies that the atmosphere-ocean system alone was unable to produce multiple equilibria, such that other components of the climate system (e.g. continental ice-sheets) were probably involved.
Molybdenum isotope composition has been emerged as an important proxy to determine paleo-redox conditions of ocean throughout Earth's history (Barling et al., 2001; Siebert et al., 2003; Arnold et al., 2004; Dahl et al., 2011). The quantitative interpretation of Mo isotope records in terms of redox conditions of ancient oceans critically depends on the Mo inputs and their isotope compositions entering the oceans. However, the inputs are poorly constrained. Mo enters the oceans predominantly via rivers (Morford et al., 1999; McManus et al., 2002, 2006). However, behavior of Mo in the estuaries (Rahaman et al., 2011) and its associated isotopic fractionation is not resolved. Therefore, it is important to identify the processes responsible for Mo removal and its associated Mo isotope fractionation in the estuaries.

Dissolved Mo isotopes (δ⁹⁸Mo) were measured in five estuaries of India to understand its behaviour in the tropical estuaries. Systematic studies were carried out in the major estuaries viz. the Narmada, Tapi and the Mandovi estuaries lying in the Arabian Sea and the Hooghly in the Bay of Bengal. δ⁹⁸Mo in all the estuaries analysed in this study is highly variable; ranges from 0.37 to 2.57‰. Dissolved δ⁹⁸Mo shows conservative mixing in the Narmada estuary. In contrast, it shows non-conservative behavior with depleted δ⁹⁸Mo in the Tapi Mandovi and the Hooghly estuaries. Depleted Mo isotope composition along with Mo loss reported earlier in the Mondovi and the Hooghly (Rahaman et al., 2011) indicate its suboxic removal where heavier isotope is being lost preferentially to the pore water. Mo sinks and associated isotope fractionation during its removal in all major global estuaries need to be considered while using Mo isotope composition to study paleo-redox condition of the global ocean.
Substantial evidence suggests that the transport of thermocline and intermediate water between the Indian and Atlantic, the so called 'Agulhas Leakage (AL)', may impact the vigour of the Atlantic Meridional Overturning Circulation (AMOC) (Weijer et al., 2002, Knorr and Lohmann, 2003) and thus be an important climate driver on various timescales. The leakage occurs through 'direct' leakage and through ring shedding events of the Agulhas Current (AC) at its retroflection off the southern tip of Africa. While satellite altimetry (Backeberg et al., 2012) data has shown a clear connection between the variation in the upstream Agulhas and the subsequent behaviour of the retroflection and ring formation, most palaeoclimate studies aimed at the reconstruction of AL within the South Atlantic (Peeters et al., 2004, Martínez-Méndez et al., 2010, Caley et al., 2012). Based on these reconstructions it has been suggested that an increased Leakage during deglaciations may effectively regulate the buoyancy of the (South) Atlantic Ocean hence impacting the strength of the AMOC.

Here we present a high–resolution multi-proxy record from a marine sediment core located in the main upstream flow of the Agulhas Current, offshore Eastern Cape Province, that shows considerable variability in upper ocean temperatures, salinity and foraminiferal marker assemblages characteristic of AL (the so called 'Agulhas Leakage Fauna', Peeters et al, (2004)) on glacial-interglacial and millennial timescales. We find that warmer surface and sub-surface water temperatures during the Holocene, MIS 3 and 5 are associated with an increased abundance of subtropical planktonic foraminiferal marker species, whereas colder surface water conditions during the LGM and MIS 4 coincide with higher abundances of Globorotalia inflata and Neogloboquadrina pachyderma (dex.) species. The occurrence of these transitional species in the AC during Southern Hemisphere cold intervals, when other evidence shows the Southern Ocean frontal system was shifted several degrees northward compared to today suggest that a stronger and/or reorganised Agulhas Return Current Circulation likely had a significant impact on the upper water column properties of the AC itself.

We suggest this upstream AC variability is strongly linked to changes in the strength of the southwest Indian Ocean subtropical gyre (STG) and modification of the Agulhas Return Current circulation. Our study is in agreement with numerical model simulations, which demonstrate that the vigour of the STG is modified by intensified and/or shifted Southern Hemisphere westerlies leading to a modification of upstream Agulhas Current. These data highlight the need for estimates of past AL based on reconstructions close to the western tip of the Agulhas Retroflection to consider temperature/salinity shifts of the Agulhas Current.
The Northeast Atlantic is a critical region to understanding the evolution of the Mediterranean Outflow Water (MOW) and its impact on the Thermohaline Circulation (THC) and the global climate. During the recent expedition of the IODP(Expedition 339), the Gulf of Cadiz was targeted for drilling as a key location for the investigation of MOW through the Gibraltar Gateway and its influence on global circulation and climate. It is also a prime area for understanding the effects of tectonic activity on evolution of the Gibraltar Gateway. This expedition drilled 5 sites in the Gulf of Cadiz and 2 off the west Iberian margin, and recovered 5.5 km of core with an average recovery of 86.4%. We present in this work the preliminary results of the studies carried out onboard the drilling RV Joides Resolution during the expedition.

We penetrated into the Miocene at two different sites and established a strong signal of MOW in the sedimentary record of the Gulf of Cadiz following opening of the Gibraltar Gateway. Preliminary results show contourite deposition from 4.2-4.5 Ma, although subsequent research will establish whether this dates from the first onset of MOW. The Pliocene succession, penetrated at four sites, shows low bottom current activity linked with a weak MOW. Significant widespread unconformities, present in all sites but with hiatuses of variable duration, are interpreted as a signal of intensified MOW, coupled with flow confinement. The Quaternary succession shows a dominant phase of contourite drift development, with two major periods of MOW intensification separated by a widespread unconformity. Following this, the final phase of drift evolution established the present contourite depositional and erosive features.

There is a significant climate control on the MOW evolution and bottom-current activity. However, from the closure of the Atlantic-Mediterranean gateways in Spain and Morocco just over 6 Ma and the opening of the Gibraltar Gateway at 5.3 Ma, there has been an even stronger tectonic control on margin development, downslope sediment transport and contourite drift evolution. Based on the timing of events recorded in the sedimentary record, we propose a long-term tectonic pulsing in the region, linked with lithospheric and asthenosphere activity. Preliminary work has also shown a remarkable record of orbital-scale variation in bulk sediment properties of contourites at several of the drift sites and a good correlation between all sites. The climate control on contourite sedimentation is clearly significant at this scale; further work will determine the nature of controls at the millennial scale.
Sequential order of Late Neogene planktic foraminiferal events have been determined at the ODP Hole 762 B situated on the Exmouth Plateau in Eastern Indian Ocean. The site is under the influence of warm Leeuwin Current from the north and cold west Australian Current from the south and records a mixture of tropical (mostly Globigerinoides group) and temperate (Globoconnela group) planktic foraminiferal species. The planktic foraminiferal biostratigraphy was integrated with the available magnetostratigraphy which yielded numerical age estimate for 32 planktic foraminiferal events. Simultaneously we have also carried out planktic foraminiferal census counting to compare the faunal trends of upwelling indicator species and mixed layer species. Our result shows a major faunal turnover during Late Pliocene, between 3.58 Ma to 2.39 Ma when about 20 planktic foraminiferal events (FOs and LOs) have been recorded. This interval closely corresponds to entire duration of Chron C2 An. We also compared the results with a closely situated ODP Hole 763A (Sinha and Singh 2008), towards south of Hole 762B, and find that most of the events are synchronous while few are diachronous also. The observed diachrony has been attributed to the changing strength of Leeuwin and West Australian Currents in response to Late Pliocene climatic fluctuations. During this interval we also observe a significant declining trend in the Mixed layer Group and increasing trend in the Upwelling indicator groups. We attribute the Late Pliocene faunal turnover to diminishing strength of the warm Leeuwin Current and more influence of cold west Australian Current in the eastern Indian Ocean and suggest that it might be related to the Northern hemisphere glaciation combined with Early Pliocene closing of the Indonesian Seaway.
Poster
Meeting the challenge of global high resolution paleoclimate modelling.

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Given the dominant role of the Ocean in Earth's energy budget, large-scale paleoclimate events are often hypothetically linked to changes in the global ocean circulation. In turn, General Circulation Models (GCMs) have been widely used to evaluate the Ocean's ability to drive and respond to paleoclimate change. However, to date almost all paleoclimate GCM simulations are limited to coarse resolution models that fail to resolve mesoscale features that are known to dominate the oceanic kinetic energy budget. Inaccuracies in the representation of mesoscale ocean features, such as coastal boundary currents and eddies, can severely limit a GCMs ability to simulate the ocean circulation and it's related climate feedbacks. This study will outline both the need for high resolution paleoclimate simulations and the physical challenges associated with it. In particular, we address the following: Where and why are mesoscale ocean features important for the modeling of paleoclimate events? How strongly does model resolution influence the deep and near surface ocean circulation? What are some of the implications of high resolution ocean modeling for biogeochemistry cycles? How is Access-OEP being used to meet the challenge of high resolution paleoclimate modeling?
Poster
Oxygen Isotope–Salinity Relationship for Paleosalinity estimation in distinct water masses of Indian & Southern Ocean

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Present interest is to accurately quantify past salinity using the oxygen isotopic abundance ($\delta^{18}O$) of carbonates to understand the climatic variability of a region. Accurate reconstruction of past regional oceanic conditions requires precise oxygen isotope-salinity relationship ($\delta^{18}O$-SSS) of the specific area under the study. In this study, we present the $\delta^{18}O$-SSS relationship of surface sea water along a transect from the west coast of India to Antarctica at every degree latitude. We identify five distinct water masses based on $\delta^{18}O$ & salinity data. Previous studies have used data from the whole of Indian Ocean or Southern ocean to obtain $\delta^{18}O$-SSS relationship. But we are able to obtain more representative $\delta^{18}O$-SSS relationship as we have segregated the data pertaining to different water masses. Additionally, to account for temporal variability in $\delta^{18}O$-SSS relationship, we have plotted our data along with that of the previous studies corresponding to the water masses identified in the present study. We observed the presence of Subtropical Front and Polar Front at 44°S and 56°S respectively. The present dataset offers to bridge the existing gap in the present global grid of the $\delta^{18}O$ dataset. The relation thus obtained can be used to reconstruct paleo-salinity in the study region as it provides a more accurate relation between $\delta^{18}O$ and SSS. It would further help to understand the different hydrological process active in the two oceans viz. Indian and Southern ocean.
A gravity core (SK-218) raised from 3307 m water depth in the western Bay of Bengal (14°02’06” lat; 82°00’12” long) was investigated to construct various foraminiferal (planktic and benthic) proxy records for the last 60 kyr BP. The age model of the core is based on 8 AMS 14C dates integrated with the oxygen isotope stratigraphy. High-resolution foraminiferal census data demonstrate major changes in assemblages at orbital to sub-orbital scales. Changes in the upper water column structure (temperature gradient, mixed layer vs thermocline depth and nutrient level) linked with fluctuations in the strength of the monsoonal climate are deduced by temporal variations of planktic foraminiferal proxy records. Record of the abundance pattern of mixed layer eutrophic species indicates that the paleo-productivity conditions at the core site are primarily controlled by the winter monsoon winds. Furthermore, the faunal evidences suggest that productivity was higher during the last glacial period as compared to the Holocene, but declined repeatedly at the millennial scale. Benthic foraminiferal assemblages were studied mainly for the temporal changes in the microhabitat categories (epifauna vs infauna), which are known to be linked with ocean bottom oxygen condition and organic carbon flux. The microhabitat patterns reveal that dissolved oxygen level of underlying waters in the western Bay of Bengal has considerably varied in the past at the millennial scale. The intervals of high abundances of epifaunal taxa and corresponding low abundances of infaunal species are indicative of oxic conditions. A coupling/decoupling between bottom oxygen condition and surface primary productivity and its global climatic implications are discussed.
Reduced flow of North Atlantic Deep Water into the Arabian Sea during Last Glacial Maxima: Evidence from $^{187}$Os/$^{188}$Os of the Arabian Seawater

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Records of Os isotope composition of the Arabian seawater since last 40 ka archived in two sediment cores taken from Arabian were tracked. The results display significant variation in $^{187}$Os/$^{188}$Os of the Arabian Sea during last 40 ka. The $^{187}$Os/$^{188}$Os of seawater in the most recent sample has a value of 1.04 ± 0.01, close to the Os isotopic composition of present day seawater (1.06 ± 0.01). The Os isotopic composition of the Arabian seawater varies in phase with that of the global ocean since last 40 ka except during the Last Glacial Maxima (LGM). During LGM, however, $^{187}$Os/$^{188}$Os deviates from the trend set by the global ocean and shows an excursion towards higher $^{187}$Os/$^{188}$Os. In addition, Os concentrations of the leachable fraction and Re contents of bulk sediments from the Arabian Sea are higher during the LGM. Higher concentrations of Re and Os in the sediments deposited during LGM indicate higher degree of anoxicity at the sediment water interface during LGM. This could be due to reduction in the oxygen content in the bottom water during LGM. Lower oxygen content in the bottom water of the Arabian Sea could have been caused by the reduced transport of polar waters (North Atlantic Deep water, NADW) into the Arabian Sea. Deviation of Os isotope composition of Arabian Seawater from the global oceanic trend and higher bottom anoxicity during LGM, thus, indicate the reduced supply of NADW to the Arabian Sea during LGM, resulting in partial isolation of the Arabian Sea from rest of the oceans during the LGM.
Poster
Seasonality reconciles the discrepancies of sea surface temperature evolution in the Indian Ocean during the last deglaciation

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Different proxies for sea surface temperature (SST) often exhibit divergent trends in tropical regions at times of terminations. In this study we report new SST records reconstructed from two commonly used paleothermometers (namely the foraminifera \textit{G. ruber} Mg/Ca and the alkenone unsaturation index) from a marine sediment core collected in the southwestern tropical Indian Ocean encompassing the last 37,000 years. Our results show that SSTs derived from the alkenone unsaturation index (U\textsuperscript{K\textsubscript{37}}) are consistently warmer than those derived from Mg/Ca by 2-3 \degree C throughout the core. In addition, the initial timing for the deglacial warming derived from U\textsuperscript{K\textsubscript{37}} SSTs started \textasciitilde15.6 ka, which is in phase with temperature stack records from Northern Hemisphere that is marked by the Bölling-Alleröd temperature rise. In contrast, Mg/Ca SSTs deglacial warming led the U\textsuperscript{K\textsubscript{37}} SST rise by 2.5 ka, and is in phase with timing from stacked temperature records from Southern Hemisphere. Moreover, the gradual decrease in $\delta^{18}O$ record derived from \textit{G. ruber} in the same core is concomitant with deglacial warming trend observed in Mg/Ca SST record. We interpret the SST records of alkenones and Mg/Ca as being skewed toward contrasting seasons, with the U\textsuperscript{K\textsubscript{37}} likely recording summer temperatures whereas the Mg/Ca SSTs recording winter temperature. Our interpretation implies that the warm season SSTs were primarily influenced by northeasterly winds transporting heat from the northern tropical Indian Ocean across the equator during austral summer. The deglacial warming trend was likely mediated by changes in the Atlantic Meridional Overturning Circulation (AMOC) at the onset of the deglaciation, as the alkenone-based SST record clearly mimics the deglacial SST trend recorded in the North Atlantic region for the earlier part of the termination. On the other hand, the glacial to interglacial SST pattern recorded by \textit{G. ruber} Mg/Ca indicates that cold season SSTs were likely mediated by climate changes occurring in the southern hemisphere, as it closely tracks the Antarctic timing of deglaciation. Such interpretation describing contrasting SST features induced by seasonally-skewed paleothermometers is also apparent in the seasonal SST trends modeled by AOGCMs, and might explain similar proxy mismatches observed in other tropical regions at the onset of the last termination.
Poster
Control of the Northern Hemisphere Ice Sheets on Glacial Climate Stability

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Glacial/interglacial cycle was marked by abrupt climate shifts of which mechanisms are generally interpreted by the bifurcation theory associated with hydrological variation in the Atlantic basin. However, the limited knowledge about hydrological change during glacial/interglacial cycles still hampers our further insight about its underlying mechanism that is supposed to be related to freshwater perturbations into the earth system in previous model studies. Here we employ a fully coupled earth system model to investigate the role played by the continental ice sheets in the Northern Hemisphere (incl. Laurentide ice sheet, Greenland ice sheet and Fennoscandian ice sheet) on abrupt climate shifts during glacial periods. We found that the sudden transition from the stadial/interstadial Atlantic meridional overturning circulation (AMOC) to the interstadial/stadial AMOC occurs when we gradually increase/decrease the ice sheets from its present-day (PD)/ Last Glacial Maximum (LGM) level to the LGM/PD level. In terms of the hydrological cycle in the Atlantic basin, the glacial climate is bistable/monostable as the ice sheets are close to far from the threshold. Furthermore, varying greenhouse gas concentrations is able to trigger the transition from stadials to interstadials as the system approaches to the threshold. These results are related to the variation of surface wind fields associated with the elevation of ice sheets and the corresponding adjustment of the local air-sea interaction over the Northeast Atlantic, which improves our understanding about abrupt events without freshwater control. Our study suggests that the fluctuation of ice sheets during glacial periods modifies the stability of glacial climate by varying the surface energy budget and developing the local positive ocean-sea ice-atmosphere feedback over the high latitudes of North Atlantic, which provides possibility for the variation of natural forcing to trigger the abrupt climate changes during glacial/interglacial cycles.