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LIST OF ABSTRACTS

Tight coupling of tropical Indo-Pacific climate variability through the last millennium: coral records

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The Indian Ocean Dipole (IOD) impacts climate and rainfall across the world, and most severely in nations surrounding the Indian Ocean. The frequency and intensity of positive IOD events increased during the 20th Century, and may continue to intensify in a warming world; however, confidence in future IOD changes is limited by known biases in model representations of the IOD and the lack of information on natural IOD variability prior to anthropogenic climate change. Here we use precisely dated and highly resolved coral records from the eastern equatorial Indian Ocean, where the signature of IOD variability is optimised, to produce a semi-continuous reconstruction of IOD variability that covers five centuries of the last millennium. Our reconstruction demonstrates that extreme positive IOD events were rare prior to 1960. However, the strongest event on record (1997) is not unprecedented as at least one event that was 27 to 42% larger occurred naturally during the 17th Century. We further show that a persistent, tight coupling existed between variability of the IOD and the El Niño-Southern Oscillation during the last millennium. Indo-Pacific coupling was characterised by weak interannual variability prior to ~1590 CE which likely altered teleconnection patterns, and anomalously strong variability during the 17th Century that caused societal upheaval in tropical Asia. A tendency for multi-decadal clustering of positive IOD events is evident in our reconstruction, which together with the identification of extreme IOD variability and persistent tropical Indo-Pacific climate coupling, has important implications for improving seasonal and decadal prediction schemes and managing the climate risks of future IOD variability

Interannual high-latitude climate reconstructions using sclerochronology

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Our understanding of North Atlantic Ocean variability within the coupled climate system is limited by the brevity of instrumental records and a deficiency of absolutely dated marine proxies. Over the past 5-10 years there has been much effort put into developing different high northern latitude sclerochronological records for reconstructing marine climate. The focus has been on cross-dating to produce long chronologies and on geochemistry of the actual growth increments themselves. Today, cross-dating and chronology building have become part of standard methodology, at least for a couple of the longer-lived bivalve species. The focus has shifted from "just" looking at the potential of obtaining long chronologies towards using the growth increment and stable isotopic data in the chronologies to isolate and reconstruct key components of North Atlantic Ocean variability. I will go through and give examples of recent developments with this field. This will hopefully provide some food for thought in terms of the potential of looking into ENSO teleconnection in the north Atlantic sector using sclerochronologial archives from high northern latitudes.

The ENSO teleconnections to the Indian summer monsoon climate through the Last Millennium as simulated by the PMIP3

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Using nine PMIP3model simulations, we study the mean summer (June-September) climate variability in India during the Last Millennium (LM; CE 0850-1849) with focus on the Medieval Warm Period (MWP) and Little Ice Age (LIA), after validation of the simulated 'current day' climate and trends.

We find that the above (below) LM-mean summer global temperatures during the MWP (LIA) are associated with relatively higher (lower) number of concurrent El Niños as compared to La Niñas. The models simulate higher (lower) Indian summer monsoon rainfall (ISMR) during the MWP (LIA) compared to the LM-mean. This is notwithstanding a strong simulated negative correlation between the timeseries of NINO3.4 index and that of the area-averaged ISMR. Interestingly, the percentage of the simulated strong El Niños associated with negative ISMR anomalies is higher in the LIA. Also, the percentage of strong La Niñas associated with positive ISMR anomalies is higher in the MWP.

This nonlinearity is explained by the simulated background climate changes, as follows. The distribution of simulated anomalous 850 hPa boreal summer velocity potential during MWP in models indicates, relative to the mean LM conditions, a zone of anomalous convergence in the central tropical Pacific flanked by two zones of divergence, i.e. a westward shift in the Walker circulation. The anomalous divergence centre in the west during the MWP also extends into the equatorial eastern Indian Ocean, triggering in an anomalous convergence zone over India and relatively higher moisture transport therein and therefore excess rainfall during the MWP as compared to the LM-mean, and hence an apparent weakening in the El Niño impact.

Paleorecords of India Summer Monsoon in Corals and Sediments: ENSO and IOD Connection

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The monsoon over Indian subcontinent is controlled by migration of narrow latitudinal wind convergence zone termed as Intertropical Convergence Zone (ITCZ). During summer (June-September), a northward shift of the ITCZ induces moisture laden south-westerly (SW) winds resulting into strong SW monsoon or Indian Summer Monsoon (ISM). Instrumental and historical records for last several decades and centuries have demonstrated a considerable variation in the Sea Surface Temperature (SST) and Indian summer monsoon (ISM) over India and nearby regions. The northern hemispheric climate is significantly influenced by ocean-atmospheric processes among which ENSO plays a crucial role. The northern Indian Ocean and the Indian subcontinent climate is impacted by ENSO as well as IOD. The coupled influence of ENSO and IOD leads to Indian summer monsoon variations. Paleorecords obtained from marine sediments and corals from the northern Indian Ocean has been investigated to look for signatures of ISM variability as a function of these oceanic processes. Effect of coupled ocean-atmospheric processes on ISM, coral growth rates would be discussed.

Dead Porites coral Sr/Ca from Panjang Island and Lampung Bay – Indonesia

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The mid-Holocene represents a radically different climate state from the present-day, largely due to natural forcings that are relatively well known. This is why the mid-Holocene is a key period for paleoclimate model studies such as the PMIP initiative. While the Medieval Climate Anomaly (MCA) is known as a warm period that lasted from 900-1300 AD. In this study, we present Sr/Ca content in dead *Porites* coral from Panjang Island (core C1 and C5) and Lampung Bay –Sunda strait (core LAM) Indonesia. Based on U/Th dating of resulted that age of core C1 and C5 is in mid Holocene ages (i.e. 5000-6000ky BP) and core LAM age is 0.81±0.03ky – 0.85±0.02ky. This results will provide an important contribution for a better understanding of tropical climate variability during this important period. The Sr/Ca data obtained so far indicates clear seasonal, interannual and decadal variability. This study will therefore significantly contribute to a better understanding of climate variability during the mid-Holocene warm period in the tropics.

Insights into ENSO spatial variability during the Holocene using monthly-resolved marine records from across the Pacific Ocean.

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The manifestation of ENSO in a locality may strongly vary through time not only for changes in the amplitude and frequency of ENSO events but also for changes in the spatial pattern of the sea surface temperature anomalies and the related teleconnections. The effects of ENSO spatial diversity are especially marked in the eastern and western boundaries of the Pacific basin. How spatial patterns of ENSO may respond to changing external forcings is one of the large uncertainties in ENSO prediction. Although it is still unknown whether ENSO spatial pattern have been affected by insolation through the Holocene, such changes would have potentially affected paleoENSO proxy reconstructions differently across the Pacific. Past changes of ENSO have been generally considered only in terms of frequency of occurrence and amplitude of a canonical ENSO, although it is now clear that the spatial dimension needs also to be considered.
Here we present results obtained from the analysis of a synthesis of monthly resolved marine records from across the Pacific. Records have been grouped geographically in 4 regions: Eastern Central, Western and South-West Pacific, and temporally into 2000-years long time slots. A reduction of interannual variability is observed consistently during the Holocene from western to eastern tropical Pacific, with a minimum in the 4-6ka slot. An opposite trend is observed in the South West Pacific where interannual variability is on the contrary increased during the Holocene with a maximum in the 4-6ka time slot. A negative relationship between seasonality and interannual variability is observed in the SW region while it is positive in the rest of the basin. This synthesized dataset is aimed to be used as a target for climate model simulations of ENSO changes through the Holocene. Monte Carlo pseudoproxy experiments indicate that uncertainties are still large and that additional dataset are needed to obtain a more detailed and robust assessment of ENSO spatial response to insolation changes in the Holocene.

Hydroclimate variability of western Thailand during the last 1400 years

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Mainland Southeast Asia is located in the central path of the Asian summer monsoon, where hydroclimatic records from speleothems have rarely been investigated. Here we present a new multi-proxy data set (δ18O, δ13C, trace elements and grayscale values) of stalagmite KPC1 from Khao Prae cave in western Thailand spanning from approximately 500 AD to 1900 AD. Our muti-proxy data reveals high variability between wet and dry periods during 500-800 AD and 1100-1300 AD, a stronger summer monsoon during 800-1100 AD, and a weaker summer monsoon and extended droughts occurred during 1300-1500 AD and after 1550 AD. In comparison with other Asian Monsoon records, the KPC1 record shows similarity with speleothem δ18O records from India, as well as lakes and tree-ring data from mainland Southeast Asia, but diverges from records from equatorial regions and the western Pacific. We conclude that hydroclimate variability in western Thailand is driven by changes in moisture transport from the Indian summer monsoon and the movement of intertropical convergence zone (ITCZ). The KPC1 record suggests drier condition between 1550 and 1900 AD, while on decadal timescales, instrumental and tree-ring data overlap indicates droughts/pluvial conditions in Southeast Asia associated with ENSO.

Local perspectives on ENSO mean states ~2300 BP and now: $\delta^{18}O$ reconstructions from the short-lived bivalves Donax obesulus and Mesodesma donacium

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The Eastern Pacific lacks long-lived organisms useful for paleoclimate reconstructions creating a need for novel archives sensitive to ENSO variability. Short-lived (<5 years) bivalves found in archaeological sites provide “snapshots” of past climatic variability (i.e., seasonal range) rather than continuous cross-dated time series (e.g., trees and corals). The short-lived intertidal bivalve Mesodesma donacium has been used to reconstruct ENSO in southern Peru; however, M. donacium is functionally extinct north of 16°S due to their vulnerability to El Niño events. We assess the short-lived (1–2 years) surf clam Donax obesulus as a complimentary archive to M. donacium in northern Peru. D. obesulus populations survive the warmer SST during El Niños, though they are vulnerable to colder SSTs associated with La Niñas. We collected live D. obesulus from the Nepeña Valley, Peru in 2012 (La Niña), 2014 (neutral), and 2016 (El Niño). We analyzed the shells for stable isotopic ($\delta^{18}O$ and $\delta^{1}3C$) and trace elemental (Sr/Ca, Mg/Ca, Ba/Ca) ratios and assessed their sensitivity to ENSO; all but Ba/Ca have seasonal cycles. D. obesulus $\delta^{18}O$shell captures SST seasonal variability with localized upwelling and advection likely influencing $\delta^{18}O$water and shell δ18O. Ba/Ca anomalies coincide with chlorophyll-a and cold events in Mg/Ca and Sr/Ca recording upwelling events. We sampled one M. donacium and six D. obesulus from a Nepeña Valley archaeological site (Caylán) to assess ENSO variability at ~2300 BP. Results from D. obesulus suggest a wider range of shell $\delta^{18}O$ signals than previously suggested from using M. donacium alone. The archaeological shells have $\delta^{18}O$shell is shifted by 0.7–1.1‰ compared to modern shells suggesting 2.5–3.3°C cooler SST and/or a shift in $\delta^{18}O$water compared to modern. We are currently analyzing 20 more archaeological shells to fully assess seasonal shifts and ENSO status for this period. So far, we find D. obesulus is a suitable compliment to M. donacium for understanding past ENSO variability.

High-resolution precipitation reconstruction of Southern California: Implications for Holocene ENSO evolution

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The El Niño Southern Oscillation (ENSO) is the leading driver of global interannual climate variability. However, the insufficient length, continuity, or resolution of current paleoclimate records and discrepancies amongst these records prevent us understand ENSO variability in centennial to millennial-scale. Therefore, the response of ENSO and ENSO teleconnection to mean climate state changes remains unclear. The field correlation analysis of historical observational data demonstrates that the interannual (with a 2–7 year periodicity) precipitation changes in Southern California is closely related to ENSO. Here we present sub-annually resolved scanning XRF Ti record from deep-sea cores collected from Santa Barbara Basin (SBB) to reveal the subannual precipitation changes in Southern California for the past 9000 years. Wavelet analysis indicates the variance of ENSO-band (2–7 years) precipitation increased after 4.4 ka, accompanied by the appearance of longer period (5–7 years) ENSO-band variance. The ENSO-band variance of precipitation is relatively low with shorter period (2–3 years) prior to 4.4 ka. The amplified ENSO-band precipitation variance in late Holocene is suggested associated with a southward shift of Intertropical Convergence Zone (ITCZ), which weakening the zonal SST gradient and trade wind across the equatorial Pacific. Four time-slice climate simulations of the Holocene support the trend of ENSO variance and its correlation with ITCZ migration. Additionally, Aleutian Low is stronger after 4.4 ka, indicating the ENSO teleconnection between tropical Pacific and Southern California is also modulated by extratropical pressure system.

Exploring the influence of ENSO on N-cycling in the Equatorial Pacific Ocean from CS-δ15N records: preliminary results

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Carbon sequestration in the ocean plays an important role in regulating climate over geological timescales. This mechanism is mostly driven by the availability of nitrogen, which limits the ocean's primary productivity and thus carbon fixation. Yet, the complex feedback mechanisms linking ocean's N-cycling and climate variability remain poorly known. The strong climate anomalies of the Equatorial Pacific, driven by El Niño Southern Oscillation (ENSO), provide an interesting context to assess the influence of climate variability on the ocean's N-cycle over short timescales.

We propose to use a recent analytical method to obtain stable nitrogen isotopes records from coral skeleton (CS-δ15N) from Palmyra Atoll. This proxy has been proven to reflect changes occurring in the ocean's nitrogen sources over geological (10,000s of years) and historical (centuries) timescales, offering the opportunity to understand how the nitrogen cycling of the surface ocean is affected by climate variability.

This study focuses on the 2015 - 2016 El Niño event and presents preliminary CS-δ15N and δ18O records from this period, as well as a longer record spanning the last 20 years. The 2015 - 2016 El Niño event was characterized by a strong depletion (- 3 ‰) of the CS-δ15N record. This anomaly is observed in three different cores, similarly, CS-δ15N records from a top core and a side core from a single colony display the same anomaly, indicating that the El Niño anomaly is a robust feature of Palmyra's CS-δ15N records. This anomaly reveals that, in the Equatorial Pacific, surface nitrogen is supplied from different sources during El Niño years compared to neutral and La Niña years. This work paves the way for investigating the link between ENSO and N-cycling over geological timescales.

Mid-Holocene paleoclimate records derived from fossil giant clam shells (*Tridacna squamoza*) from the Java Sea.

Mary Elliot

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Fossil shells of marine bivalves such as giant *Tridacna* provide information on past environments with seasonal resolutions. Similarly to corals, changes in mean seasonal cycles and inter-annual variability can be reconstructed by sequentially analyzing the annual layers of calcium carbonate. Previous inter-comparison studies conducted on modern material have shown that seasonally resolved records derived from marine bivalves (*Tridacna gigas*) and corals (*Porites*) provide similar information. This step has been necessary in order to combine these data sets into global databases. In this study, we have conducted a new calibration study of modern *Tridacna squamosa* which have been collected in several localities around Indonesia. Stable isotope (del-18O) and trace element profiles (Mg/Ca, Ba/Ca) have been measured and compared to local hydrology : sea surface temperature, rainfall and productivity. Mg/Ca and SST exhibit a clear linear relationship with similar equations regardless of the area of sampling. Additionally, comparison of measured and estimated del-18O confirm that this species precipitates their shells in isotopic equilibrium. The results from the calibration experiments are used to compare modern and fossil samples collected from Belitung Island located in the heart of the Java Sea. Our study shows that the mid-Holocene period, around 6ka, was slightly colder (mean temperature difference was 1°C) and lower salinity compared to modern conditions. These results are compared to model studies and other coral based data collected from locations further North in the South China Sea which show a northward displacement of the Intertropical Convergence zone during this period increasing rainfall rates over land and reducing precipitation in the Southern region of the South China Sea.

An extended record of Indian Ocean Dipole variability from Indonesian Corals

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The Indian Ocean Dipole (IOD) is an ocean-atmosphere climate oscillation within the Indian Ocean basin and one of Australasia's key climate drivers that influences the distribution of rainfall across the region. Future projections of IOD activity suggests that extreme positive IOD events may become more frequent with greenhouse warming leading to an increase in occurrence of extreme climate and weather events in regions influenced by the IOD. However, the short duration of instrumental records and biases in model representations of the IOD make it difficult to confidently separate anthropogenic-related trends from natural variability. To better understand natural IOD variability, high-resolution reconstructions of the Indian Ocean sea surface temperature (SST) are needed to provide a comprehensive view of IOD upwelling activity prior to the Industrial Revolution.

In this research, a fossil Porites coral has been used reconstruct past SST from the Sunda Strait, Indonesia. The southern Sunda Strait (6.5ºS, 105.5ºE) region is a key area for measuring IOD activity, as the cold upwelling waters in the eastern Indian Ocean, associated with a positive IOD event have a clear signature here that is captured by geochemical changes in coral skeletal material. The focus of this project is on a 205 year, ~monthly resolution δ18O record from a coral tsunami block that spans the interval 1668 to 1872. The coral temperature record has been combined with a modern coral record and historical ship log book records from the region to create a 350-year record of tropical Indian Ocean SSTs. This extended SST reconstruction reveals insights into the frequency and intensity of positive IOD events prior to anthropogenic climate change.

Coral records of tropical Pacific temperature seasonality, interannual variability, and mean climate during the last deglaciation (IODP Expedition 310 - Tahiti)

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Links between tropical Pacific seasonal, interannual and orbital climate variability are of strong relevance for an improved understanding of past and future behavior of the El Niño-Southern Oscillation (ENSO), the leading mode of interannual climate variability. For the tropical Pacific Ocean, reconstructions of seasonal and interannual surface water conditions are available from a growing network of seasonally resolved coral (and mollusk) records that span time intervals of the Holocene. However, comparable information is sparse for the last deglaciation, because coral reefs that grew during this period of substantial change in mean climate and rapid climate perturbations on centennial to millennial timescales are difficult to access, as sea level was substantially lower than today. IODP Expedition 310 to Tahiti was an international coordinated effort to drill fossil coral reefs of last deglacial age in the tropical South Pacific Ocean, at water depths between 40 and 118 m. Seasonally resolved records of fossil corals recovered during Expedition 310 suggest that ENSO was active around 15.0 kyr ago, during the Heinrich Stadial 1 cold interval of the Northern Hemisphere, and that interannual sea surface temperature (SST) variability at typical ENSO periods was pronounced at Tahiti, unlike today, implying a southward expansion or shift of ENSO SST anomalies at that time. Furthermore, Expedition 310 coral records provide new evidence for relative cooling in the tropical South Pacific at 12.4 kyr ago, during the Younger Dryas cold reversal of the Northern Hemisphere. Fueled by a new collection of modern Tahiti corals recovered from the vicinity of the Expedition 310 drill sites to robustly assess the uncertainties in our reconstructions, we have started to study the relatively short Expedition 310 coral records to contribute to an improved understanding of the seasonal response of tropical Pacific SST variability to abrupt climate perturbations during the last deglaciation.

Asami, R, Felis, T, Deschamps, P, Hanawa, K, Iryu, Y, Bard, E, Durand, N and Murayama, M (2009) Evidence for tropical South Pacific climate change during the Younger Dryas and the Bølling-Allerød from geochemical records of fossil Tahiti corals. Earth and Planetary Science Letters, 288(1-2). 96-107. doi:10.1016/j.epsl.2009.09.011

Felis, T, Merkel, U, Asami, R, Deschamps, P, Hathorne, EC, Kölling, M, Bard, E, Cabioch, G, Durand, N, Prange, M, Schulz, M, Cahyarini, SY and Pfeiffer, M (2012) Pronounced interannual variability in tropical South Pacific temperatures during Heinrich Stadial 1. Nature Communications, 3. 965. doi:10.1038/ncomms1973

Felis, T., Oster, C, Asami, R, Deschamps, P, Hathorne, EC, and Merkel, U (in progress) Tropical Pacific temperature seasonality around Meltwater Pulse-1A from IODP Expedition 310 corals. DFG project number 408139156

Hathorne, EC, Felis, T, James, RH and Thomas, AL (2011) Laser ablation ICP-MS screening of corals for diagenetically affected areas applied to Tahiti corals from the last deglaciation. Geochimica et Cosmochimica Acta, 75. 1490-1506. doi:10.1016/j.gca.2010.12.011

New high-resolution Holocene ENSO record from Lake Te Roto, Cook Islands: a varve-based chronology approach

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The South Pacific Convergence Zone (SPCZ) is the most extensive convective cloud band in the Southern Hemisphere, which generates a strong rainfall gradient in the South Pacific basin. On inter-annual to inter-decadal timescales, Pacific climate phenomena, such as the El Niño-Southern Oscillation (ENSO) cause the SPCZ to shift position. Indeed, El Niño events cause the SPCZ to move north-eastwards and extreme El Niños, make the SPCZ join the Intertropical Convergence Zone (ITCZ). Polynesian islands experience severe droughts during such events, while SPCZ Zonal phenomenon is predicted to become more frequent under a warming world. Moreover, a major shift in the position of the SPCZ and ITCZ has occurred around the time of Polynesian migration (850-1150 BCE), resulting in a prolonged north-eastward shift of the SPCZ that has strongly modified climate conditions on the islands. Nevertheless, the relationship between ENSO and the hydrological pattern of individual Pacific Islands is still poorly constrained. Thus, the South Pacific is considered to be one of the most vulnerable areas to extreme climate events on Earth. However, only few instrumental data records are available from this critical region and these are often partial and short (<50 years). Therefore, high-resolution quantitative palaeoclimate data are a research priority to fully understand major South Pacific climate dynamics (i.e. SPCZ, ENSO). This information is vital for the population of 13 million inhabiting the 1395 South Pacific islands, who especially rely on rainfall for freshwater and food security. A new high-resolution climate record from a laminated sediment core, collected in Lake Te Roto (Atiu, Cook Islands) will be generated. Cook Islands are ideally located across the SPCZ contraction axis to study the SPCZ movement and consequently ENSO behaviour. Thanks to a promising method based on varve chronology, a detailed intra-annual record covering main climatic transitions for the last 8000 years will be produced. This record will allow to extend our understanding of hydroclimatological change in the South Pacific, linked to the SPCZ and ENSO dynamics and thus, to the colonisation of Eastern Polynesia.

Deciphering the variability in Mg/Ca and stable oxygen isotopes of individual foraminifera

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Foraminifera are commonly used in paleoclimate reconstructions as they occur throughout the world's oceans and are often abundantly preserved in the sediments. Traditionally, foraminifera-based proxies like δ18O and Mg/Ca are analyzed on pooled specimens of a single species. Analysis of single specimens of foraminifera allows reconstructing climate variability on timescales related to El Niño-Southern Oscillation (ENSO) or seasonality. However, quantitative calibrations between the statistics of individual foraminiferal analyses (IFA) and climate variability are still missing. We performed Mg/Ca and δ18O measurements on single specimens from core-top sediments from different settings to better understand the signal recorded by individual foraminifera. We used three species of planktic foraminifera (G. ruber (s.s.), T. sacculifer, and N. dutertrei) from the Indo-Pacific Warm Pool (IPWP) and one species (G. ruber (pink)) from the Gulf of Mexico (GoM). Mean values for the different species of Mg/Ca vs calculated δ18O temperatures agree with published calibration equations. IFA statistics (both mean and standard deviation) of Mg/Ca and δ18O between the different sites show a strong relationship indicating that both proxies are influenced by a common factor, most likely temperature variations during calcification. This strongly supports the use of IFA to reconstruct climate variability. However, our combined IFA data for the different species only show a weak relationship to seasonal and interannual temperature changes, especially when seasonal variability increases at a location. This suggests that the season and depth habitat of the foraminifera strongly affect IFA variability, such that ecology needs to be considered when reconstructing past climate variability.

A work in progress – a reconstruction of hydrological changes at Christmas Island (Indian Ocean) from high resolution Porities corals

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Variability of Indonesian Throughflow and Borneo Runoff during the last 14 kyr

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We present a high resolution (~20 to 100 years temporal resolution) reconstruction of hydrological changes in the Makassar Strait over the last 14 kyr from Core SO217-18517 retrieved off the Mahakam Delta (1°32.198'S, 117°33.756'E; 698 m water depth) during the SO217 Makassar-Java (MAJA) Cruise. Sea surface temperatures, based on Mg/Ca of Globigerinoides ruber and alkenone UK'37, and sea water δ18O reconstructions, based on G. ruber δ18O and Mg/Ca, in combination with sortable silt grain-size measurements and X-ray fluorescence (XRF) core scanner derived elemental data provide evidence for increased precipitation during the Bølling-Allerød (BA) and early Holocene and for warmer and more saline surface waters and a decrease in the intensity of the Indonesian Throughflow (ITF) during the Younger Dryas (YD). XRF derived Log (Zr/Rb) records, sortable silt data and increased sedimentation rates indicate decreased winnowing, interpreted as a slowdown of the ITF thermocline flow during the YD. We attribute this decline in ITF intensity to slowdown of the Atlantic Meridional Overturning Circulation (AMOC) during the YD. We suggest that changes in Makassar Strait surface hydrology during this interval of northern hemisphere cooling and southern hemisphere warming were related to a southward displacement of the Intertropical Convergence Zone.

From geodynamics to biodiversity in SE Asia: Belitung is the key

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Combining geomorphological observations with numerical simulations of coral reef growth and shallow seismic stratigraphy, we show that SE Asia is vertically unstable, far more than generally thought. To the West, coral reefs and geomorphological data -around Belitung in particular- reveal that the Sunda shelf is subsiding, and that the intermittent regime of transgressions only prevailed over the last 400,000 yr. Prior to that MIS 11, Sundaland was permanently emerged. Because the Sunda shelf is very shallow, these new data provide important insights into the Pleistocene paleogeography, with implications on the interactions between the solid Earth and climate, oceanography and dispersal of species, including hominids. The dynamics of the biodiversity in this region is consistently regarded as solely contingent on glacial sea level oscillations, with interglacials high stands creating intermittent dispersal barriers between disjunct landmasses. Phylogeographic data for terrestrial organisms conform to this scenario: available divergence time estimates reveal an eight-fold increase in the rate of vicariance between landmasses of Sundaland after MIS 11, coeval to the onset of episodic flooding of the Sunda shelf. Conversely in Wallacea, to the East, the archipelago is uplifting. The region of uplift delineates the coral triangle, one of the most striking biodiversity hotspots, and this is no coincidence: uplift excites a variety of mechanisms of insular speciation, that may explain the specific richness of Wallacea. We relate vertical land motion to transient dynamic topography in the Indo-Australian subduction zone. Subsidence in the West and uplift in the East owe their origin to the dynamics of the Earth's mantle, where viscous forces drown Sundaland and emerge Wallacea during the Plio-Quaternary, thereby profoundly remodeling the paleogeography of Pleistocene SE Asia. These results highlight how reconsidering the paleogeographic setting of Sundaland challenges our understanding of the origin of biodiversity of SE Asia, as formerly envisioned by A.R. Wallace.

Review of Koutavas lab ENSO reconstructions from individual foraminifera d18O

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I review 15 years of efforts and publications from my lab to illuminate past ENSO behavior from d18O of individual foraminifera from the eastern Pacific. I argue that this method, while presently imperfect but developing rapidly, has the greatest potential for discovery because of: (1) ubiquitous and inexhaustible material on the sea floor; (2) possibility for replication (multiple cores, sites, regions); (3) multiple applicable proxies (d18O and Mg/Ca); (4) multiple species recording surface and thermocline environments; (5) robust proxies and analytical methods. The greatest challenges are: (1) careful understanding of species depth, season and vertical migration patterns; (2) bioturbation in slow accumulation cores; (3) separation of annual, interannual, decadal and longer signals; (4) method calibrations using modern core-tops; (5) use of suitable statistical methods.

U-Th systematics in marine carbonate archives of "extreme" environments: identifying and overcoming limitations caused by early diagenesis

Volker LIEBETRAU

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Reliable proxy records of extreme environments receive increasing attention in order to identify the full range of environmental and climate changes within different time intervals of the past. Furthermore, in case of biogenic archives they may provide realistic estimates of species dependent resilience potential and adaptability to extreme conditions. Marine carbonates represent important paleo-proxy archives as environmental conditions are recorded geochemically during their formation. Combined with U/Th age dating climatic variability spanning geological time scales can be determined. The accuracy of U-Th based proxy approaches is largely dependent on the degree of diagenesis experienced. Due to elevated concentrations of U and Sr and other trace metals, when compared to calcitic species, especially aragonitic coral and shell structures provide sensitive and for precise U-Th geochronology suitable recorder. Nevertheless, often they need to be considered as potential open systems with regard to high susceptibility for alterations in uranium and thorium isotope systematics by secondary precipitation, dissolution, recrystallization, uptake and exchange processes. Although the analytical techniques developed impressively to extreme precisions and sample throughput efficiencies limitations introduced by diagenesis are still of major impact on the accuracy and robustness of geochronological records.

General improvements are reached by combining micro-CT pre-investigation with micro-sampling techniques in order to identify and subsample pristine remains of the primary skeleton. This approach is supported by electron micro probe, scanning electron microscopy and epi-fluorescence microscopy to identify skeleton parts characterized by secondary mineral precipitation and organic components, indicating mineral alteration by the activity of endolithic organisms. Applied on recent to sub-recent coral micro atolls and fossil Tridacna spp. from Zanzibar (Tanzania), this study reveals small-scale heterogeneities in U-Th systematics of different time scales. In addition, the impact of potential variations of initial U-Th isotope uptake systematics in extreme environments including cold water coral habitats will be discussed with regard to natural limitations on theoretical and analytical precision. Besides the aspect of long-term diagenesis and secondary mineralization this study investigates

the impact of biologically-driven geochemical carbonate alteration during and shortly after corals live span.

The Influence of geormorphology and land use on the preservation of an El Niño frequency and intensity signal in three Andean lakes

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Laguna Pallcacocha, a high-alpine lake in the Ecuadorian Andes, is one of the most oft-cited records of Holocene ENSO variability. Intense convective storm activity during El Niño events generates flooding and erosion of coarse grained, light colored, clastic material which is deposited on the lake floor as clearly identifiable laminations. This 15,000 year record of alluviation, however, is not matched in proximal lacustrine sediment records. Laguna Martin and Laguna Fondococha each contain coarser laminations which indicate comparatively more intense flood events than the finely laminated Pallcacocha. We use a high-resolution digital elevation model (DEM) to investigate the geomorphic properties of each basin which lead to the deposition and preservation of clastic flood layers. Additionally, we use the Watershed Erosion Prediction Project (WEPP) model to investigate patterns of sediment erosion and its relationship to land use changes in order to better constrain modern sedimentation history. Watersheds with higher order streams connecting exposed clastic material to the lake basin and greater degrees of channelization as indicated by basin-scale hypsometry tend to preserve a greater number of clastic layers. Additionally, all basins examined with the WEPP model experience drastic increases in soil loss immediately following periods of wildfire, an important consideration when calibrating the modern sedimentary record to the instrumental history of ENSO.

Millennial to seasonal scale views of El Niño-Southern Oscillation from central Pacific corals

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El Niño-Southern Oscillation (ENSO) is naturally highly variable on interannual to decadal scales making it difficult to detect a possible response to climate forcing. Despite the high variability, several lines of evidence from tropical corals, mollusc, lake sediments, and foraminifera suggest that 5,000-3,000 years ago ENSO variance was on average reduced by 60-80% compared to the present day. We investigate the seasonal-to-centennial variation in ENSO amplitude and tropical climate during this ENSO 'quiet period' 5,000-3,000 years ago using a new Sr/Ca SST record from a 175-year-long 4,300-year-old coral, and new $\delta^{18}O$ and Sr/Ca results from a similar-aged ~180-year-long Porites sp. coral. Both corals were discovered on Kiritimati (Christmas) Island, an optimal ENSO 'centre of action' in the central tropical Pacific. Together, these corals confirm a reduction in ENSO amplitude and that ENSO amplitude is modulated on multi-decadal scales. Composites of month-by-month changes in Sr/Ca-SST show an unprecedented view of ENSO and detail which seasonal-scale features of ENSO are an inherent part of the system and which are subject to change under altered climate states. We also investigate the millennial timescale changes in ENSO variance using combine coral oxygen isotope ($\delta^{18}O$) data from central Pacific corals and a suite of forced and unforced simulations conducted using the CSIRO Mk3L and GFDL CM2.1 climate system models. On millennial timescales, the coral data reveal a statistically significant increase in ENSO variance over the past 6,000 years. This trend is not reproduced by the unforced model simulations, but can be reproduced once orbital forcing is taken into account. Together these views of past ENSO may contribute to advances in understanding the response of ENSO to future changes in climate forcings.

The evidence of sea level changes from Malaysia: what happened during early to mid -Holocene?

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The pattern of post-last glacial maximum (ca. 20,000 years BP) sea-level rise from ca. 120 m below current sea level differs geographically due to variations in glacio-isostacy (Fleming et al., 1998). At near field sites, the changes of sea level was affected by the continuing isostatic rebound, while at intermediate-field sites, combination of eustacy and collapse of the glacial forebulge (Horton et al., 2009; Kemp et al., 2009, 2017). In contrast, at far-field sites such as the Malay-Thai Peninsula located on the Sundaland tectonic block (Simandjuntak and Barber, 1996; Hall and Morley, 2004; Simons et al., 2007) at the western margin of the southern South China Sea (SCS), the sea-level record is relatively unaffected by ice-sheet effects, although hydro-isostatic effects are still important (Clark et al., 1978; Fleming et al., 1998; Mitrovica and Milne, 2002; Horton et al., 2005; Hanebuth et al., 2008). Following rapid sea-level rise in the latest Pleistocene a sea-level maximum up to 5 m above current sea-level occurred in this region between. 6,000 and 4,000 years BP (Geyh et al. 1979; Tija, 1996; Hesp et al., 1998; Kamaludin, 2003; Horton et al., 2005; Bird et al., 2007, 2010; Hanebuth et al., 2011; Tjia and Sharifah Mastura, S.A., 2013; Bradley et al., 2016; Parham, 2016). Since that time, sea level fell to its current level approximately 300 to 500 years ago based on index points in Horton et al. (2005). Sea level rose over the past three centuries and on the east coast of peninsular Malaysia is currently rising at ca. 3 mm yr-1 (JUPEM, 2000; Culver et al., 2015). Trisirisatayawong et al. (2011), using GPS-corrected tide gauge data in the Gulf of Thailand region immediately to the north of peninsular Malaysia, demonstrated significant spatial variation in rates of sea-level change but rates of rise were still above the global estimate of ca. 1.8 mm yr-1 for the 20th century (e.g., Jevrejeva et al., 2008; Cazaneve and Llovel, 2010). The central location of the Malay-Thai Peninsula within the Asian monsoon system makes this area important, not only in terms of sea-level change, but also in terms of the geologic record that is available for understanding monsoonal variations through time (Brijker et al., 2007; Oppo et al., 2009), and the impact of those changes on coastal systems. Several studies along the Malaysia waters has been carried out to understand and reconstruct paleo temperature and salinity changes within this region. Additionally, benthic foraminifera has also been used to determine the sea level changes at east and west coast of Malaysia. The quantification of benthic foraminifera has provide several useful models that can be used to reconstruct high resolution sea level changes during Holocene. The application of the foraminiferal based transfer function to Kedah (core) samples (North Malacca Straits) produced three appealing sea-level index points from the early Holocene. The relative sea-level was ~5m lower from present level during 9830 cal BP. Meanwhile in 8250 cal BP and 7960 cal BP, the sea-level was ~8 m and ~ 3 m lower than present level respectively. The relative sea-level at Malacca Straits in 9830 cal BP was 12 m higher than the predictions made by other researchers within the same region but lower compared to those observed in Langkawi. Malay-Thai Peninsula occupies a strategic location with

respect to coastal response to both climate and sea-level change over the past several thousand years. Therefore more studies should be carried out to understand the response of coastal system towards climate and sea level changes.

Synthesizing coral δ18O with high-resolution ocean models to explore mechanisms of Indo-Pacific oceanic exchange through the Indonesian Throughflow

Sujata MURTY
WHOI

The Indonesian Throughflow (ITF) serves as an important oceanic teleconnection for Indo-Pacific climate, altering heat and buoyancy transport from the Pacific to Indian Oceans. For example, equatorial Pacific wind forcing transmitted through the ITF impacts interannual to interdecadal Indian Ocean thermocline depth and heat content, with implications for preconditioning Indian Ocean Dipole events. Yet the modulation of Indian Ocean thermal properties at seasonal timescales is still poorly understood. Here we synthesize coral δ18O records, instrumental indices (e.g. El Niño Southern Oscillation (ENSO), Asian Monsoon), and simulated ocean variability (e.g. heat content, mixed layer depth, sea surface salinity (SSS), sea surface temperature) from state-of-the-art NEMO ocean model hindcasts to explore drivers of variability from seasonal to multi-decadal timescales. All coral sites are located within main ITF pathways (Makassar and Lombok Straits) and are influenced by monsoon-driven South China Sea surface waters during boreal winter that obstruct surface ITF flow and reduce heat transport to the Indian Ocean. Makassar and Lombok Strait monthly and season-averaged (boreal winter and summer) coral δ18O co-varies with simulated SSS, subsurface heat content anomalies (50-350m) and mixed layer depth at the coral sites as well as in the eastern Indian Ocean. Notably, the variability in these coral and model responses reveals sensitivity to phase changes in ENSO, the Interdecadal Pacific Oscillation and the East Asian Winter Monsoon in the mid- to late-20th century. These results collectively suggest that the paleoproxy records are capturing important features of regional hydrography and Indo-Pacific exchange, including responses to ENSO variability. Such proxy-model comparison is thus critical for understanding the interacting drivers of Maritime Continent and eastern Indian Ocean variability related to changes in ITF oceanic teleconnections over the 19th and 20th centuries.

A work in progress – a reconstruction of hydrological changes at Christmas Island (Indian Ocean) from high resolution Porities corals

Celeste PALLONE
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The El-Niño Southern Oscillation (ENSO) is the main system determining interannual variability in the tropical Pacific today and its influence in the past is still uncertain. The mean state of the eastern equatorial Pacific (EEP) and ENSO over the Holocene and last glacial maximum are widely debated, but there are fewer records of primary productivity and thermocline structure that extend over 50,000 years. An analysis of two deep sea sediment cores from the location of modern upwelling in the EEP near the Panama Basin aims to clarify the history of ENSO in region from Marine Isotope Stage (MIS) 6 to the present. EEP thermocline structure will be reconstructed from $\delta^{18}O$ records of multiple foraminifera species. Time series of primary productivity and dust fluxes will be determined from the sedimentary 231Pa/230Th activity ratio and 230Th-normalized 232Th flux, respectively. Results will be analyzed in the context of previously published research on the time period. The role of the precessional orbital cycle in determining mean ENSO state will also be explored.

Green Sahara and its impact on ENSO variability

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The evolution of the El Nino-Southern Oscillation (ENSO) during the Holocene remains uncertain. In particular, a host of new paleoclimate records suggest that ENSO internal variability or other external forcings may have dwarfed the fairly modest ENSO response to precessional insolation changes simulated in climate models. Here, using fully coupled ocean- atmosphere model simulations, we show that accounting for a vegetated and less dusty Sahara during the mid-Holocene relative to preindustrial climate can reduce ENSO variability by 25%, more than twice the decrease obtained using orbital forcing alone. We identify changes in tropical Atlantic mean state and variability caused by the momentous strength- ening of the West Africa Monsoon (WAM) as critical factors in amplifying ENSO's response to insolation forcing through changes in the Walker circulation. Our results thus suggest that potential changes in the WAM due to anthropogenic warming may influence ENSO variability in the future as well.

Ice Core-derived Climate Reconstruction from Tropical Papua Glaciers, Indonesia and Their Recent Retreat

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The impact of climate change in Indonesia is evident. The most likely convincing evidence is the glacier recession on ice fields near Puncak Jaya in Papua, Indonesia, the highest peak between the Himalayas and the Andes and the last remaining tropical glaciers in the West Pacific Warm Pool. Total ice area has shrunk from about 19 km2 during ~1850 to about 1 km2 in 2006 or only 5% of glaciers area remains. Most recent aerial photographs and satellite measurements were taken in between 2010 and 2018 shows continuing the ice retreat. Previous studies suggest that atmospheric warming is very likely to be the main driver for the recession of these glaciers, although other factors still remain as possible causes. To better understand the main driver of glacier recession on these ice fields, BMKG in collaboration with BPCRC, LDEO, and PTFI has conducted the ice core paleoclimate study since the mid-2010 and the glacier survey has been annually conducted to monitor the accumulation stake. Two ~32 meter long ice cores to bedrock recovered in mid-2010 are used to reconstruct the tropical Pacific climate variability on interannual (ENSO) to interdecadal timescales. Oxygen isotopic ratios show a positive linear trend (~0.012‰ per year), tracking the observed atmospheric warming, and capture changes in upper air temperatures along the tropical bands. Recent photographs and measurements of a 30 meter accumulation stake on the summit of one of these glaciers show a very recent ~5.4-fold increase in the rate of thinning that was augmented by the strong 2015/16 El Niño. Through this study, Indonesia has significantly contributed to the current discussion on global climate changes and tropical climate sciences. In the future, BMKG will continue to monitor the existence of these glaciers and engages other scientists to involve in this research.

ENSO in the tropical Indian Ocean: stationary and non-stationary teleconnections

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The El Niño Southern Oscillation (ENSO) is the dominant mode of interannual climate variability in the tropical Indian Ocean and leads to a basin-wide warming in boreal winter. El Niño events occur more frequently during recent decades and are thought to contribute to the strong warming of the tropical and, in particular, the western Indian Ocean during the 20th century. The ENSO teleconnection is documented in coral temperature reconstructions from the tropical Indian Ocean that are based on coral Sr/Ca. The impact of ENSO on Indian Ocean sea surface temperatures appears to be stable from the Little Ice Age to the present day. The warming during El Nino events also feeds back on rainfall over the Indian Ocean and surrounding continents, but coral reconstructions of hydrological changes suggest that this teleconnection is non-stationary over time, and depends on the state of climate in the Indian Ocean. However, the long-term warming of the Indian Ocean and its impact on the ENSO teleconnection is currently not fully understood. This talk discusses potential contributions from coral proxy reconstructions of sea surface temperature and hydrology to resolve this issue.

A 400-year stable isotope in tree-ring teak and ENSO variability

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We constructed a 400-year-long teak oxygen isotope chronology that covered the period of AD 1616–2015. This included data from 19 living teak trees from Mae Hong Son province, northwest Thailand. Instead of pooling the tree-ring material from several trees as aforementioned, we constructed the chronology by averaging an isotope series from individual trees that were well inter-correlated, allowing precise dating control on all individual tree-ring δ18O values. For this approach, our chronology is covered by a number of at least 4 trees after 1680. The tree-ring δ18O ranges between 20.81–26.90‰, and the average is 24.44‰. It showed significant positive correlation with relative humidity in Apr. ($r=0.309$, $p<0.05$) and a significant negative correlation in Sep. ($r=-.276$, $p<.05$) and in ASO ($r=-.247$, $p<.05$). There is the highest significant negative correlation with rainfall in JJASO ($r=-.346$, $p<.01$). Our tree-ring δ18O has a significant positive correlation with minimum temperature only in the month of Sep. ($r=.250$, $p<.05$) and the highest positive correlations with maximum temperatures in JJASO ($r=.309$, $p<.05$). We found significant positive relationships between our tree-ring δ18O and the Multivariation ENSO Index (MEI). ENSO influenced the tree-ring δ18O more significantly in the period of 1870–1939 when compared to the period during 1940–2015, and this corresponded to periods of weaker and stronger Indian monsoon intensity. It can conclude that oxygen isotopes in tree-ring teak have the potential to be used to study the hydroclimate circulation in Thailand.

Keywords: Teak Tree-ring oxygen isotopes, Asian summer monsoon, ENSO

Surface temperature and Precipitation Variability in Indonesia from 6,000 to 615,000 years ago: First Insight from Low-Resolution Coupled Model Simulation

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An attempt to analyse the climate dynamics of Indonesian Waters using the results of a set of 13-time slice experiments simulated by CCSM3-DGVM model is challenging. It was carried out to study global climate variability between and within the Quaternary interglacials of Marine Isotope Stage (MIS) 1, 5, 11, 13, and 15. During boreal summer (June-July-August-September), in most of Indonesia, seasonal surface temperature anomalies can largely be explained by local insolation anomalies induced by the astronomical forcing. However, at some dates, climate feedback may modify the surface temperature response in Indonesia, most pronounced in open water close to Indian Ocean and Pacific Ocean. The warmest sea surface temperature (SST) anomaly up to 1˚ K is in Banda Sea at 125 ka (MIS 5) and 579 ka (MIS 15) compared to Pre-Industrial (PI) conditions. The coolest SST anomaly down to –2˚ K is equally distributed in Indonesian Waters. During boreal winter, most of the moderate cooling over large portions of the land and the waters of Indonesia is also associated with local insolation. The interesting part in this study, a dipole and tripole precipitation pattern is captured in the western part of the Indonesian Waters, Indian Ocean to Banda Sea, and the eastern part of Indonesian Waters during boreal summer up to 3.6 mm/day of rainfall anomaly. The results of this study are expected to be used as basic information to predict the climate in Indonesia for the present and future along the role in alleviating the impacts of climate change which is in line with the goals of the IPCC.

Oxygen isotope record from Lakshadweep coral

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The northern Indian ocean experiences Indian monsoon annually. During summer, the monsoonal wind induces vertical mixing resulting in sea surface temperature changes. These changes are recorded by the corals growing in the region. Proxy records from these corals can provide important understanding towards past sea surface condition changes and its relation with monsoon. Signature of ENSO phenomenon which is believed to affect Indian monsoon could also be recorded in these corals. In view of this, corals from Lakshadweep region are being analysed for its geochemical and isotopic proxy records. The coral oxygen isotopic values were calibrated with sea surface temperature for SST reconstruction. The mean centered $\delta^{18}O$ values show highly enriched values during 1999 and 2011 monsoon indicating relatively cooler SST. These monsoon periods precede co-occurrence of negative Indian Ocean Dipole and La Nina event. Relative cooling of surface water in Lakshadweep region due to these events can be recorded in oxygen isotopic composition of these corals.

Interannual records of the Kuroshio Intrusion linked with ENSO

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The Luzon Strait (LS) hosts the largest transport of water between the Western Pacific Ocean (WPO) and the South China Sea (SCS). The transport through the strait, dominated by the westward propagation of the Kuroshio Intrusion, influences the climate and circulation of the SCS. While numerical models have investigated the interannual variability of the transport and subsequent water exchange across the LS, a lack of long-term on-site records prevents a general consensus on the transport rates, variability, and drivers. Corals offer high-resolution, continuous histories of radiocarbon (Δ14C) content of the seawater dissolved inorganic carbon, allowing us to track changes in surface ocean processes including interactions with the sub-surface layers through upwelling. Seasonal and annual Δ14C samples from Houbihu, Taiwan, and Palaui, Philippines, located on either side of the strait, are compared with the WPO and SCS Δ14C records to examine the spatial and temporal Δ14C variability in the region. The northern site, Houbihu, is highly impacted by sub-tropical processes including advection from the East Asian Winter Monsoon (EAWM) winds. The southern site, Palaui, is sensitive to changes in the North Equatorial Current bifurcation latitude (NBL) which is primarily influenced by the El Niño Southern Oscillation (ENSO). While the two sites are being impacted by independent processes, the difference between these sites allows us to investigate changes in water exchange between the WPO and the SCS across the strait. A box model describing the differences between the two sites and surrounding regions indicates that a weaker EAWM slows the flow of water from the Kuroshio Current into the SCS whereas variation in the ENSO can increase the rate of exchange into the SCS.

The role of ENSO in clastic sedimentation in Laguna Pallcacocha Ecuador: An Overview

Donald.T. RODBELL

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Laguna Pallcacocha is located at 4060 masl and 2.77°S, 79.23° in a small cirque in Las Cajas National Park, Ecuador, a region with one of the highest densities of lakes globally. It was first cored in 1993 with the aim to document the timing of deglaciation of the Cajas Plateau, and the core retrieved was unlike any other obtained from a cirque lake in the tropical Andes. The bar-code-like visual stratigraphy and the high-frequency oscillations in organic carbon and magnetic susceptibility provide clear evidence of high-frequency clastic sedimentation events, which contrast sharply with the long-term watershed stability evidenced in cores from the vast majority of glacial lakes in the region. The age model for the early Pallcacocha cores is based on 15 radiocarbon ages and multiple geochemically distinct tephra (0.1-1.0 cm thick); time series analyses reveal sub-decadal variance in clastic sedimentation events that appear to increase in frequency through the Holocene, especially after ca. 5 ka. In July 1999, the first surface core capturing the sediment-water interface was obtained and subsequently dated by ^{210}Pb, which reveals that most of the clastic laminae in the upper 40 cm of the sediment core match approximately with "strong" to "very strong" El Nino events from the Quinn and Neall (1992) chronology, including the historic very strong 1998 *CE* event, which is seen as a clear clastic lamina in the core top. The relationship between ENSO activity and precipitation at the Pallcacocha location has been plagued by a lack of long pluviometric data sets from region. Schneider et al. (2017) were first to evaluate rainfall data from the Torreadora meteorological station, located 1.8 km southeast of Pallcacocha and spanning the four years from 2012-2016 *CE*. Coupled with more distally located meteorological stations they concluded that intense rainfall is equally likely to be generated by La Niña and El Niño events. In addition, the apparent lack of correlation between their ^{210}Pb-dated Pallcacocha record and historic El Niño events, led Schneider et al. (2017) to challenge the role of El Niño in generating clastic laminae in Laguna Pallcacocha. In an effort to sort out the role of ENSO on rainfall in the Pallcacocha watershed, Kiefer and Karamperidou (2019) used a mesoscale weather prediction model to investigate the regional circulation dynamics and precipitation response during different "flavors" of ENSO: Eastern Pacific (EP), Central Pacific (CP), coastal El Niño (COA), and La Niña (LN). Their results reveal that the most intense rainfall over the Pallcacocha watershed in the past ~26 years is associated with Coastal El Niño events; all other flavors of ENSO yield much lower precipitation intensities. This conclusion has been confirmed through recent analysis of 3 local meterological stations, which reveal that although easterly winds dominate, high intensity rainfall is associated with southwesterly airflow and intense precipitation is localized to with a few kilometers of the Pacific-Atlantic drainage divide, within the region where Pallcacocha is located. Completion in 1994 *CE* of the major highway between Cuenca and Guayaquil, which passes within 0.5 km of Laguna Pallcacocha, appears to have impacted lake water quality, with diatom evidence indicating

increased lake eutrophication. In addition, new sedimentological evidence shows a recent shift in the drainage pattern within the Laguna Pallcacocha delta, likely following a large debris flow. These combined events may explain the anomalous character of the uppermost sediment in many Cajas lakes, including Pallcacocha, which record an increase in massive organic (gyttja) sedimentation and a lack of clear clastic events.

ENSO's relationship to tropical Pacific background state

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Reconstructions of ENSO using individual foraminifera have the capability to provide information on sea surface temperature variability that spans multiple climate background states. Such data allows us to investigate the role that climate boundary conditions, such as insolation, glacial state, or tropical Pacific background state play in modulating ENSO behavior. Here I present data from a single foraminifera based El Niño amplitude reconstruction from the Central Tropical Pacific Line Islands. This record spans multiple climate background states, including changes in insolation, CO2, glacial conditions and sea level, as well as varying E-W SST gradients and changes in the tropical thermocline. I will discuss methods for determining ENSO behavior, particularly El Niño amplitude, in our single foraminifera record, including Q-Q analysis, and discuss our results from discrete time intervals spanning the last 285,000 years. Our data show a significant correlation between El Niño amplitude and the depth of the Equatorial Counter Current, which is inversely related to the depth of the mixed-layer at the equator. This relationship is consistent across glacial and interglacial conditions, suggesting that the background state of the tropical Pacific has significant influence on ENSO behavior.

Using coral-based data assimilation to investigate the response of the tropics to volcanic eruptions

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Despite well documented disparities in simulations of historical tropical climate variability, we can create skillful reconstructions of the tropical Pacific Ocean using offline data assimilation within the framework of the Last Millennium Reanalysis (Hakim et al. 2016). Within this methodological framework, we combine coral geochemical archives (δ18O, Sr/Ca), accessed through the NOAA NCEI Paleoclimate and PAGES 2K Networks, and constrain them within the dynamics, spatial teleconnections, and intervariable relationships of the CMIP5 Past1000 experiments. This analysis allows for a novel investigation of tropical climate variability over the 19th and 20th century. However, notable inconsistencies in ENSO reconstructions arise during a period of expected strong volcanic aerosol loading. We systematically evaluate the source of the discrepancies using proxy-fraction and single-proxy data assimilation experiments, varying the proxy system models, and finally modifying the priors (CMIP5 Past1000 simulations). We find that the covariance patterns of the CMIP5 Past1000 experiments have difficulty constraining the post eruption response in proxy-dense regions, such as the western Pacific. We find greater agreement amongst all proxies when altering the spatial covariance relationships in the western Pacific and some improvement when considering multivariate proxy system models. This work has implications for the scientific understanding of the climatic response to perturbations in Earth's radiative budget and tropical climate dynamics.

Mid-Holocene ENSO change in PMIP3: Preliminary Results

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Proxy records of the El Nino Southern Oscillation (ENSO) along the tropical Pacific show less intensity and less frequent events during the mid-Holocene than today. Earlier modelling studies suggest a stronger boreal summer-to-autumn insolation as the main driver to weaken the ENSO. Stronger insolation decreases the low-level westerly anomaly over the central Pacific, thus, suppresses the development of El Nino via the Bjerknes feedback mechanism.

Simulations for the mid-Holocene and the pre-Industrial scenarios were conducted by coupled atmosphere-ocean models from major institutions around the world under the Paleoclimate Model Inter-comparison Project Phase 3 (PMIP3). In this study, we individually explored ENSO change in nine models involved in PMIP3.

Nine models show various longitude-frequency shift of the ENSO spectral along the tropical Pacific between the mid-Holocene and the pre-Industrial simulations. However, the longitude-frequency shift is coherent between the low-level zonal wind and the sea surface temperature for most of the models. Such coherency confirmed the role of the Bjerknes feedback mechanism as suggested by the earlier studies.

Simulated climate evolution over the past 9000 years using AWI-ESM

Xiaoxu SHI
AWI

Taking advantage of an state-of-the-art earth system model (AWI-ESM) with high resolution, both time-slice and transient simulations for the Holocene are performed. In this study, the evolution of the climate over the last 9000 years are explored, with a focus on monsoon and ENSO behavior. In addition, the effect of model resolution on simulated climate is also investigated.

High Frequency ENSO during The AMOC slow down

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Paleoclimate studies and proxy evidence show that the Atlantic meridional overturning circulation (AMOC) plays an important role in the millennial climate variations during the last glacial period. These are hints that sudden changes of the AMOC cause large and abrupt climate changes over many parts of the globe during the last glacial and interglacial period. Climate scientists have expected the AMOC to decline long-term under global warming. A measurement of the AMOC's strength since 2004 indicated a decline trend 10 times larger than expected. This study aims to investigate on how does the El Niño Southern Oscillation (ENSO) reacts during AMOC slows down in the North Atlantic freshwater hosing experiment using atmosphere-ocean coupled general circulation model CCSM3. Results show that ENSO has shifted into higher frequency due to changes in its seasonality which has larger variance during the maximum of the AMOC slows down.

ENSO modulation of seasonal rainfall and extremes in Indonesia

Supari SUPARI

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This paper provides a detailed description of how ENSO events affect seasonal and extreme precipitation over Indonesia. Daily precipitation data from 97 stations across Indonesia covering the period from 1981-2012 were used to investigate the effects of El Niño and La Niña on extreme precipitation characteristics including intensity, frequency and duration, as defined based on a subset of the Expert Team on Climate Change Detection and Indices (ETCCDI). Although anomalous signals in these three indices were consistent with those of total rainfall, anomalies in the duration of extremes (i.e. consecutive dry days (CDD) and consecutive wet days (CWD)) were much more robust. El Niño impacts were particularly prominent during June-July-August (JJA) and September-October-November (SON), when anomalously dry conditions were experienced throughout the country. However, from SON, a wet anomaly appeared over northern Sumatra, later expanding eastward during December-January-February (DJF) and March-April-May (MAM), creating contrasting conditions of wet in the west and dry in the east. We attribute this apparent eastward expansion of a wet anomaly during El Niño progression to the equatorial convergence of two anti-cyclonic circulations, one residing north of the equator and the other south of the equator. These anti-cyclonic circulations strengthen and weaken according to seasonal changes and their coupling with regional seas, hence shaping moisture transport and convergence. During La Niña events, the eastward expansion of an opposite (i.e. dry) anomaly was also present but less prominent than that of El Niño. We attribute this to differences in regional ocean – atmosphere coupling, which result in the contrasting seasonal evolution of the two corresponding anomalous cyclonic circulations and in turn suggests the strong nonlinearity of El Niño and La Niña responses over the Maritime Continent. Based on the seasonal behaviour of anomalous CDD and CWD, we propose five sub-divisions of the Indonesian region for both El Niño and La Niña.

The three musketeers: Paleo-ENSO, paleo-IOD, and a new, equatorial mode of Indian Ocean variability

Kaustubh THIRUMALAI
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Here I will present paleo-SST reconstructions and climate model simulations focusing on the Indo-Pacific and Indian Ocean region at the Last Glacial Maximum (LGM), ~20,000 yrs ago. During the LGM, individual foraminiferal analyses (IFA) provide a methodology wherein sample distributions of monthly SST variance can be estimated. The statistics of these estimates can be used to infer the magnitude of past seasonality and interannual variability in the oceans. I will review existing IFA studies for the LGM and present a new dataset from four cores in the eastern tropical Indian Ocean. Next, I will show results from an ensemble of LGM simulations with an emphasis on seasonality and interannual variability in the Indo-Pacific region. The simulations indicate a massive increase in Indian Ocean climate variability under LGM conditions, consistent with the new reconstructions. Seeking to refine the cause of this increase, when the centers-of-action of the El Niño/Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD) are sequentially disabled in the simulations, a large portion of variance remains unexplained. A testable hypothesis for this increase in seasonal & interannual climate variability arises from the simulations; they reveal the emergence of a quasi-oscillatory equatorial mode of variability in the Indian Ocean that is independent of ENSO, and different from the IOD in its timing, spatial footprint, and coupled ocean-atmospheric precursors. Instead, the dynamics of this mode mirrors those of ENSO in the modern Pacific Ocean and shows that the Indian Ocean is capable of harboring stronger variability than currently observed. I will discuss the consistency of this hypothesis with available IFA datasets and explore shortfalls and further tests of the “Indian Ocean El Niño” hypothesis.

Sediment archives of ENSO variability: New insights and novel proxies

Diane THOMPSON

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Although paleoclimate "proxy" reconstructions have significantly improved our understanding of past El Nino-Southern Oscillation (ENSO) variability, considerable uncertainties remain due to discrepancies among proxy archives, particularly those with different temporal resolution and /or sensitivity to oceanic or atmospheric response of the coupled ENSO system. For example, there is strong (and growing) evidence from the eastern equatorial Pacific sediment records for an intensification of ENSO variability (i.e., stronger and/or more frequent ENSO events) in the late Holocene, while existing fossil coral records from the central Pacific suggest only a weak change across this interval. Here I present the results of 10 years of ongoing lake monitoring in the Galapagos Islands, which aimed to tackle these discrepancies via an improved understanding of the way the ENSO signal is recorded in two important lake sediment archives (Genovesa and Bainbridge Crater Lakes). These monitoring data have transformed the way we now interpret carbonate precipitation in these sediment records, which form during dry, La Niña conditions. Applying this new interpretation at Bainbridge Crater Lake, we demonstrate that ENSO events of *both phases* were generally less frequent during the mid-Holocene (~6100-4000 cal. years BP) relative to the last ~1500 cal. years. Importantly, this long-term monitoring has also identified novel proxies that may be utilized to further separate individual El Niño events from changes in the background state and/or seasonality: (1) Flamingo guano-driven $\delta^{15}N$ variability in Bainbridge lake, and (2) stratification and productivity-induced changes in molybdenum redox geochemistry in Genovesa lake. Application of these techniques to extruded sediment samples suggests that both of these proxies hold great promise in separating individual ENSO events from the background state of the system (as all recent ENSO events are captured by rapid $\delta^{15}N$ declines and significant enrichments in Mo burial, respectively). These results emphasize the importance of such long-term monitoring efforts for not only improving interpretations of our proxies, but also for identifying promising new directions for reconstructing past ENSO variability.

SANDY-TUDHOPE

Reconstructing past climatic changes using lake sediments in the Argentine Central Andes

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The Central Andes of NW Argentina cover the climatic transition zone between the South American Monsoon System and the Pacific Westerlies, which are the two main meteorological precipitation systems of southern South America. This region is sensitive to shifts in the climatic transition zone, as well as the superposition of other large-scale phenomena (e.g., El Niño Southern Oscillation, Pacific Decadal Oscillation) and therefore constitutes a key region for obtaining realistic regional reconstructions of past climate variability. In this sense, the timing and extent of precipitation changes prior to the instrumental period in this area are still largely unknown, preventing a better understanding of the long-term drivers and their effects over the Argentine Central Andes.
The focus of my PhD project is to decipher past climatic changes in NW Argentina, with a special focus on variations in precipitation during the Holocene. For this, I am using high-resolution techniques in lacustrine records from two lakes located in extremely different environments. Laguna Comedero is a highly variable shallow lake located in the subtropical forest of the Yungas in the foothill of the Argentine Eastern Cordillera (2035 m asl). The present-day climate is subtropical humid with total annual rainfall around 1470 mm. Laguna Peinado is located in the southern Altiplano-Puna Plateau (3820 m asl). Annual average precipitation sums do not exceed 150–200 mm, while potential evaporation (>1500 m yr-1) greatly exceeds precipitation (Grosjean et al. 1997)
Several studies report that a significant fraction of precipitation interannual variability in the high Andes is associated with the ENSO phenomenon (Vuille et al. 2000; Garreaud and Aceituno 2001). However, due to the limited number of meteorological stations in some regions of the Argentine Central Andes, there is still a great uncertainty regarding frequency and intensity of rainfall events during ENSO cycles. According to Bookhagen and Strecker (2011) higher-elevation sectors in the Eastern Cordillera and the Altiplano-Puna Plateau locally receive more than twice as much rainfall during negative ENSO (La Niña) years. Conversely, during El Niño events the Altiplano-Puna Plateau often experience drought conditions (Thompson et al. 1992). Studies focusing on paleoENSO events in southern South America are still scarce. According to the majority of ENSO reconstructions, the Medieval Climate Anomaly (MCA) was characterized by more El Niño dominated conditions. Yet, other studies suggest a more La Niña dominated MCA (Cobb et al. 2003; Khider et al. 2011; Mann et al. 2009) and more frequent and stronger El Niño events during the Little Ice Age. Data from the Argentine Central Andes are considerably limited in comparison with research carried out in northern Chile, Bolivia and Peru. In order to understand past climate changes and evolution in precipitation patterns and extreme events, it is necessary to increase the number of paleoclimate reconstructions in this region.

Omani coral record suggests that Western Indian Ocean upwelling uncouples from the Indian Ocean Dipole during the global-warming hiatus

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The Indian Ocean Dipole (IOD) is an interannual mode of climate variability in the Indian Ocean that has intensified with 20th century global-warming. However, instrumental data shows a global-warming hiatus between the late-1990s and 2015. It is presently not clear how the global-warming hiatus affects modes of climate variability. Here, we present a 26-year long record of Sr/Ca and δ18O from a Porites coral in the Gulf of Oman. Sea surface temperature (SSTanom) is calculated from Sr/Ca ratios, and seawater δ18O (δ18Osw-anom) is estimated by subtracting the temperature component from coral δ18O. Our δ18Osw-anom record reveals a significant regime shift in 1999, towards lower mean δ18Osw values, reflecting intensified upwelling in the western Indian Ocean. Prior to the 1999 regime shift, our SSTanom and δ18Osw-anom show a clear IOD signature, with higher values in the summer of positive-IOD years due to weakened upwelling. The IOD signature in Omani coral disappears with the overall intensification of upwelling after the 1999 regime shift. The inferred increase in upwelling is likely driven by an intensified Walker circulation during the global-warming hiatus. Upwelling in the Western Indian Ocean uncouples from the IOD.

Pliocene ENSO: Coral evidences of robust interannual variability and environmental conditions during Pliocene warm period

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Global mean temperature and atmospheric carbon dioxide concentrations during the Pliocene warm period (PWP; 5-3 Ma) were substantially high as much as those predicted for near-term climate change. Experimental and model studies are suggesting that recent past and future global warming and ocean acidification due to rising atmospheric carbon dioxide concentrations would have dramatically influenced on the calcification processes of marine organisms. However, few direct evidences have existed to address how warming and acidification would play it for marine ecosystem. Tropical corals could record long term growth histories in annual bands of their skeletons as well as marine environments during their growth periods up to several hundreds years.

We discovered well-preserved fossil Porites corals at the muddy sand layer of Tartaro formation in Luzon island, the northern part of Philippine during the middle of PWP (3.5-3.8Ma); one of the most possible periods for analog to Earth's climate future. We screened and selected two exceptionally well-preserved fossil specimens for signs of diagenetic alternation using microanalysis of thin sections using the high-energy synchrotron X-ray diffraction analysis in combination with microstructural observation by scanning electronic microscopy and optical microscopic observation (Watanabe et al., 2011). We applied the geochemical analysis (d18O, d13C, d15N, and trace elements from the fossil PWP corals in order to address the relationship between marine environments and coral growth characteristics. The detail profiles of carbon and oxygen isotopes of coral records indicate that significant reduced growth rate occurred in summer during the two different environments of PWP.

Our coral geochemical and physiological data from this unique time window confirm future predictions that temperature rising and ocean acidification may lead to severely reduced coral growth but also imply the possibility that corals can still survive even in such marine environments of future warming climate with shifting the growth seasonal characteristics if the future climate change could provide enough intervals for tropical coral to be adapted.

We will discuss in the presentation about other possible stresses for coral growth such as nutrient (Yamazaki et al., 2013) and marine pollution facing differently on modern and PWP corals to understand more realistically expected future images of marine ecosystems.

References

Watanabe, T., Suzuki, A., Minobe, S., Kawashima, T., Kameo, K., Minoshima, K., Aguilar, Y.M., Wani, R., Kawahata, H., Sowa, K., Nagai, T., Kase, T. (2011) Permanent El Niño during the Pliocene warm period not supported by coral evidence, Nature 471, 209–211

Yamazaki, A. Watanabe, T., Takahata, N., Sano, Y., Tsunogai, U.(2013) Nitrogen isotopes in intra-crystal coralline aragonites, Chemical Geology, 351, 276–280

Tight coupling of tropical Indo-Pacific climate variability through the last millennium: climate simulations

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The Indian Ocean Dipole (IOD) impacts climate and rainfall across the world, and most severely in nations surrounding the Indian Ocean. The frequency and intensity of positive IOD events increased during the 20th Century, and may continue to intensify in a warming world; however, confidence in future IOD changes is limited by known biases in model representations of the IOD and the lack of information on natural IOD variability prior to anthropogenic climate change. Here we use precisely dated and highly resolved coral records from the eastern equatorial Indian Ocean, where the signature of IOD variability is optimised, to produce a semi-continuous reconstruction of IOD variability that covers five centuries of the last millennium. Our reconstruction demonstrates that extreme positive IOD events were rare prior to 1960. However, the strongest event on record (1997) is not unprecedented as at least one event that was 27 to 42% larger occurred naturally during the 17th Century. We further show that a persistent, tight coupling existed between variability of the IOD and the El Niño-Southern Oscillation during the last millennium. Indo-Pacific coupling was characterised by weak interannual variability prior to ~1590 CE which likely altered teleconnection patterns, and anomalously strong variability during the 17th Century that caused societal upheaval in tropical Asia. A tendency for multi-decadal clustering of positive IOD events is evident in our reconstruction, which together with the identification of extreme IOD variability and persistent tropical Indo-Pacific climate coupling, has important implications for improving seasonal and decadal prediction schemes and managing the climate risks of future IOD variability

A 150-year history of the Kuroshio Current and its interaction with ENSO

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The Kuroshio Current is a major global ocean current that drives the physical ocean-atmosphere system with heat transport from tropical to temperate zones in the North Pacific Ocean. The transportation and migration of Kuroshio are closely related climate in north Pacific Ocean. We reconstruct the variability of the Kuroshio transport and migration using coral skeletal nitrogen and oxygen isotopes (δ15Ncoral and □^{18}Ocoral) and demonstrate the relationship with El-Niño–Southern Oscillation (ENSO), representative climate variability in north Pacific Ocean.

Coral cores from Porites were collected from Cape Shionomisaki, Tatsukushi Bay, and Koshiki Island during 2008-2009 on the Pacific coast of Japan, which is located on the northern front of the Kuroshio Current. The Kuroshio path is invariable at Tatsukushi Bay off, and Tatsukushi coral recorded the variation of Kuroshio transport continuously (Yamazaki et al.,2016). Tatsukushi δ15Ncoral was used as a proxy to record the δ15N of nitrate (δ15Nnitrate) controlled by the upwelling of subtropical subsurface water (δ15Nnitrate; +2~+3‰), and δ15Ncoral was negatively correlated with observations of the Kuroshio transport ($R = 0.69$, $P < 0.001$) and the 2 year lagged PDO index ($R = 0.63$, $P < 0.005$) from 1972 to 2007. The 150-year record of δ15Ncoral suggested that the Kuroshio transport varied with ~25-year cycle, and the amplitude became more stable, and the volume was intensified through the twentieth century. The Kuroshio transport was intensified by the La Niña state in the early 1900s and by the El Niño-PDO state after the 1920s. Our results suggested that the Kuroshio transport was influenced by the combined climate modes of ENSO and PDO during the last century.
To capture the migration of Kuroshio path, we reconstructed oxygen isotope ratios in coral skeletons from Cape Shionomisaki, Tastukushi Bay, and Koshiki Island during 1944-2008. The straight path of Kuroshio ordinary locates on Cape Shionomisaki and Tatsukushi Bay, but the meander path migrates southward from Cape Shionomisaki. The difference oxygen isotope anomalies between Cape Shionomisaki and Tatsukushi Bay became 1‰ larger in maximum with the occurrence of Kuroshio meander, and its decadal variability correspond coral oxygen isotope changes reported from Koshiki Island. Increasing coral oxygen isotopes at Cape Shionomisaki with the occurrence of Kuroshio meander suggested that the loss of the turbulence on the northern ridge of the Kuroshio axis bringing cold and lower oxygen isotope seawater from subsurface. Decadal changes in the differences of coral oxygen isotopes between Cape Shionomisaki and Tatsukushi Bay suggested East Asian Monsoon and/or ENSO variability related to the migration of Kuroshio path.

References

Yamazaki, A., T. Watanabe, U. Tsunogai, F. Iwase, and H. Yamano (2016), A 150-year variation of the Kuroshio transport inferred from coral nitrogen isotope signature, Paleoceanography, 31(6), 838-846, doi:10.1002/2015PA002880.
Watanabe, T., T. Kawamura, A. Yamazaki, M. Murayama, and H. Yamano (2014), A 106-year monthly coral record reveals that the East Asian summer monsoon modulates winter PDO variability, Geophysical Research Letters, doi: 10.1002/2014GL060037

Coral-based reconstruction of ENSO impacts of SST and hydrological balance in Borneo and the Indonesian Throughflow

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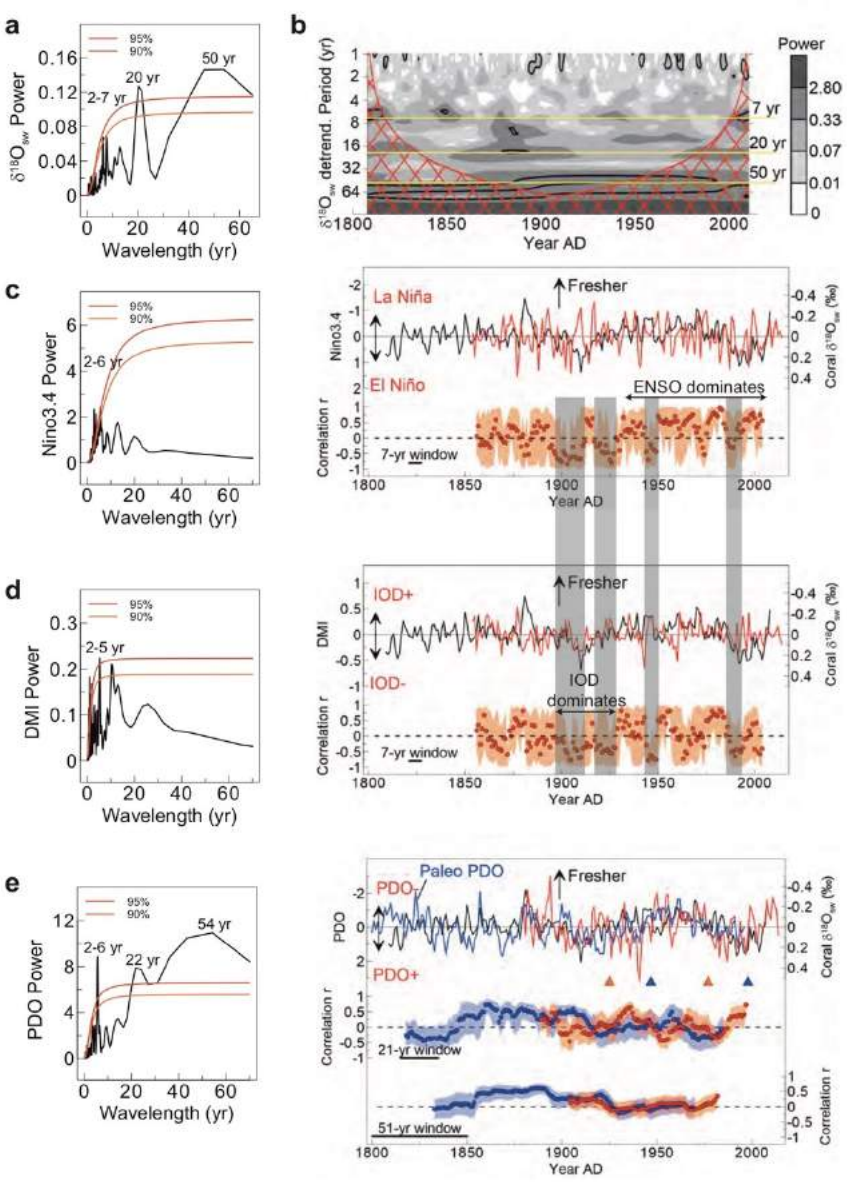
Extreme climate events, such as the El Niño in 1997/1998 and 2015/16, led to drought and strong wild fires causing dramatic forest loss in the southeast Asian region including Borneo. Since the 1980s, the effects of extreme climate events are exacerbated by rapid urbanization in Borneo and accelerated deforestation and soil erosion. However, studies quantifying the impact of interannual ENSO and long-term climatic and anthropogenic change affecting Borneo's coastal marine environments are lacking, in particular for coral reef ecosystems. Here, I will show results from coral cores collected in the Miri-Sibuti Coral Reefs Marine Park, Borneo (Malaysia) where we reconstructed the spatio-temporal dynamics of sea surface temperature and oxygen isotopic composition of seawater based on paired stable isotope and Sr/Ca measurements. Reconstructed δ18Osw revealed positive excursion during major El Niño events of 1997/98, 2005, 2010 and 2015/16 indicating drought conditions with less river runoff, rainfall and higher salinities. La Niña's were in general associated with lower δ18Osw. Our results suggest that coral records from northern Borneo are invaluable archives to detect regional ENSO impacts and their interaction with the East Asian Monsoon on the hydrological balance in the southern South China Sea.

A second major region of ENSO impact is the leakage of the Indonesian Throughflow into the Indian Ocean between the Timor Sea and the northwest Australian shelf, as well as Cocos Keeling atoll in the southeastern Indian Ocean. Here we present a 200-year bimonthly record of geochemical parameters (δ18O-Sr/Ca) measured on Cocos Keeling corals tracking sea surface temperature (SST; Sr/Ca) and sea surface δ18Osw (Fig. 1; Hennekam et al., 2018). Our results showed that over the past 200 years ITF leakage into SETIO is dominated by the El Niño Southern Oscillation and Indian Ocean Dipole. Our data suggests an alternating dominance of ENSO and IOD on ITF leakage during the last 150 years, with ENSO showing a stronger influence during the last 80 years, but the IOD appears more important for interannual variability in ITF leakage in the early 20th century. Current research in my team builds on the Cocos Keeling work and aims to provide improved ITF leakage signatures from the northwest Australian shelf (Timor Sea).

Figure 1 – Cocos Keeling δ18Osw record compared to climate indices of ENSO, IOD and the PDO between 1800 and 2008 (after Hennekam et al., 2018).

Hennekam, R., Zinke, J., ten Have, M., Brummer, G.J.A. and Reichart, G.-J. (2018) Cocos (Keeling) corals reveal 200 years of multi-decadal modulation of southeast Indian Ocean hydrology by Indonesian Throughflow. Paleocean. and Paleoclim. 33, DOI: 10.1002/2017PA003181.



Lionel JAFFRÈS

« Mesurer la taille du Monde » program
CEARC / Le Grain / Marine Sciences For Society - Brest, France

Director, author and actor, he questions the political and poetic dimensions of desire. For this purpose, he develops, in particular, a research around the scenic writings of reality and shared writings. Artistic director of many works of the Théâtre du Grain in Brest, he is committed to the emergence of individual and collective expression, allowing those who formulate it to access emancipatory reflection. To do this, he is inspired by individual or collective encounters and testimonies that are the raw material of his writing and directing work.

In this process of sharing and exchanging with "witnesses", it partners with teams of scientists who share the same concerns. It participates in "Mesurer la taille du Monde" program and works with the CEARC laboratory and the Marine Sciences For Society network of researchers.

Thus, between 2016 and 2018, it was immersed in three oceanographic campaigns; Acclimate in the Southern Ocean (Claire Waelbroeck - LSCE), Rockall-Mingulay in the North Atlantic (Mary Eliott - LPG) and HydroSed in Taiwan (Christophe Colin - GEOPS).

In May 2016, he coordinated the Anthoposcène festival as part of the international ARTisticc project (Belmont Fund).

Currently, he is working on writing and directing a show based on his artistic and scientific experiences over the past ten years.