Can we precisely date and source the late Holocene Carpentaria Impact?

Background: From early 536 AD until mid 537 AD, the sun shone for about 4 hours each day, producing a climate downturn accompanied by famine, drought, and unrest. The Carpentaria impact may be the source of the "worst weather in the last 2000 years", but it is poorly dated and its source crater is unknown. We found a crater candidate in shallow water near the mouth of a river. The Carpentaria impact layer is characterized from distal, deep water (>60 meters depth) cores, as more proximal cores in shallow water are extensively stirred by cyclones. We found impact glass, magnetite spherules and shocked ilmenite in a narrow layer with high magnetic susceptibility. The two glass types from the Carpentaria impact resemble glasses found in a circa 536 AD layer in the GISP2 ice core from Greenland. The high concentrations of magnetic minerals in the layer cannot come from the sediments of glacial Lake Carpentaria beneath the layer. Although the lake sediments are more magnetic than typical marine sediment, they are not magnetic enough. We infer that iron rich sediment deposited by rivers draining tropical, lateritic soil may be required. The ejecta layer also contains oolites, which typically form in water depths of less than 4 meters.

Analysis Required: The student will examine distal core samples in hand as well as new more proximal samples. The proximal samples will be as close as possible to the crater candidate, but from water depths exceeding 60 meters. The student will pick large open marine benthic foraminifera for more accurate dating of the distal cores. The species will be selected to exclude contamination from the sediments of glacial Lake Carpentaria. The student will also pick oolites; previously found to be most abundant in the impact ejecta layer. The oolites will be evaluated for their oxygen isotope signature to see if they exhibit fluvial influences. In addition, the concentration of oolites versus depth and bulk magnetic susceptibility will be used to evaluate the concentration of impact ejecta versus depth in each core. Students will also evaluate which species of shells and microplankton in the ejecta layer might have a near shore origin. If possible, the student will look for dwarf, lagoonal species of foraminifera to characterize their relative abundance inside and outside the impact ejecta layer. This work will better date the event and constrain the location of the source crater.

Prerequisites: The student should enjoy microscope and laboratory work. The student should be interested in geology and extraterrestrial impacts.

Thesis Mentors: Dr. Dallas Abbott, Lamont-Doherty Earth Observatory of Columbia University, dallas@ldeo.columbia.edu, Bärbel Hönisch, hoenish@ldeo.columbia.edu

Did a Tsunami Generated by an Oceanic Impact Produce Major Erosion in the Hudson River?

Background: We found a layer in the Hudson River that is the most profound erosional unconformity in the river. This layer may extend as far north as the Indian Point nuclear power plant. In some cases, we can show that the layer contains shocked minerals and pelagic foraminifera, markers for impact and oceanic origin respectively. One foraminifer contains shot in FeNiCr rich bits that might be derived from impact melt. Still other foraminifera are coated with Sn, sometimes rich in Ni and/or Zn. Our problem is to date this layer and to prove that the layer was formed by an impact-generated tsunami rather than a storm surge.

The literature predicts that storm surges cannot produce erosion of the bottom in water depths that exceed 3 meters. In contrast tsunamis can produce erosion of the bottom in water depths >10 meters. We have found five cores, all from water depths >3 meters that show an abrupt increase in density with increasing depth. These might represent erosional unconformities generated by a large tsunami. In practice, we need to prove an origin from a tsunami generated by an oceanic impact by demonstrating that: 1) the layer is graded, 2) the basal layer is a lag deposit, 3) the layer contains shocked quartz, shocked ilmenite and impact glass, 4) the layer increases in thickness towards the ocean and 5) the population of foraminifera differs from that of storm surge deposits.

Analysis Required: The student will measure reconnaissance magnetic susceptibility on the cores around the depths showing an abrupt increase in bulk density on core logs. The student will sample the layer and measure detailed magnetic susceptibility on individual samples. By sieving the samples and documenting the coarse fraction versus depth, the student can determine if the layers are graded. The student will also examine our prospective tsunami layer under the microscope, looking for shocked minerals, glass fragments and impact breccias at the base of the layer and for metal coated and uncoated foraminifera at the top of the layer. The student will examine picked material, first with a scanning electron microscope (SEM) and later with a petrographic microscope. The goal is to characterize the glasses and minerals in the impact ejecta layer, both to determine the likely location of the source crater and to ascertain if all of the ejecta layers are from the same impact event. In addition, the student will pick carbon rich material of opportunity to date the impact layer.

Prerequisites: Experience with wet sieving and ability to identify foraminifera and minerals is desirable. Student should enjoy laboratory and microscope work. Student should have a strong interest in geology and extraterrestrial impacts.

Thesis Mentors: Dallas Abbott, dallas@ldeo.columbia.edu, 856-365-8664,
Bärbel Hönisch, hoenish@ldeo.columbia.edu

What happened to the water? Experimental investigations of subglacial drainage

Background: If the Earth's major ice sheets melted, sea level would rise approximately 65 meters, enough to submerge a 20-story building. Sea level during past periods moderately warmer than today has been as much as 11 meters higher but more commonly has been around six meters higher, about as much as a typical two-story house. Flooding of this magnitude would cause major infrastructure problems along the Eastern seaboard of the U.S. Contributions of sea level rise come from ice sheet areas bordering the ocean where much of the base of the ice sheet is below sea level. Rates of ice flow are dependent on the seaward boundary with either open ocean or ice shelves affecting inland ice streams. Dynamic feedbacks between the configuration of ocean, ice shelves, and ice streams determine the resultant sea level rise.

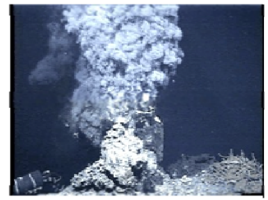
Beneath the Greenland and Antarctic Ice Sheets, a natural icy plumbing system drains subglacial water along the seaward margin and affects how the ice-loss feedbacks operate. The flowing water forms pockets, ponds, pools, and lakes, and the subglacial water subsequently drains downstream following the flow of the ice sheet. Scientists have looked at drainage much like overland flow. However, observations show that the drainage is episodic with lakes filling and draining. A ceiling of overlying ice seals the water above an underlying bed. The overlying ice presses into the subglacial system, causing water to spread over the base of an ice sheet. Depending on flow conditions, the water can weaken the bed, enhance slip, and aid ice flow. Thus, the rate of ice discharge to the global oceans is related to water at the base of ice sheets. Reliable estimates of sea level rise thus require knowledge of processes, including water drainage, beneath the major ice sheets. Despite this critical dependence, the base of the ice sheet is not easily observable: How does subglacial water drainage operate? When ice presses down into a water system, what happens? In order to answer such questions, we need to observe and quantify drainage. Table top experiments are an attractive alternative because they scale up to glaciers and ice sheets. This project aims to quantify water movement using analog table top experiments.

Analysis required: This project will use tabletop analog experiments of gelatin (the ice sheet or glacier) and a fluid that is injected beneath the gelatin. The project will look at how fluid drains to the exterior of the gelatin. The summer will be spent developing and running experiments in a laboratory. Measurements will be made using a digital camera and a laser. Subsequent data analysis will be a part of the project.

Prerequisites: None, but a background in Excel or Matlab is a plus.

Thesis mentor: Timothy Creyts (845-365-8368, tcreyts@ldeo.columbia.edu)

How Fast is Your Smokestack?



Background: A variety of Earth and environmental processes involve turbulent buoyant jets spanning a large range of spatial scales (see photos at right). Often, obtaining the volumetric flow rate in this type of flow is difficult. However, great progress has been made using optical image analysis techniques for analyzing turbulent buoyant jet flow, and my lab is currently developing a specialized camera system that will be able to provide flow rates by analyzing the video it collects. A set of laboratory experiments will need to be conducted during the development of this camera system.

The student working on this research project will help build a laboratory apparatus to generate a turbulent buoyant jet with known flow rates. The student will conduct simple experiments using the apparatus to collect video imagery of the simulated flows, and will apply image analysis techniques on these image sequences to help calibrate the system and refine the analysis software.

This project will emphasize hands-on laboratory experience during the construction and data collection phases of this project. The student will have the opportunity to engage in programming and data analysis at a level tailored to his or her interests and abilities.

Prerequisites: This is a project that would be well-suited for a student interested in engineering, laboratory modeling, computer programming, and fluid dynamics.

Thesis Mentor: Timothy Crone
(crone@ldeo.columbia.edu)

What controls the Agulhas Leakage? Assessing the role of the Subtropical Front

Background: The intensity of global thermohaline circulation (THC) is a key player in Earth's climate. The Agulhas Current system is an important part of the warm return route of the THC. The Agulhas Current transports surface and intermediate waters from the tropical Indian Ocean southward along the east coast of Africa. As it passes the southern tip of Africa, the Current turns eastward, back towards the Indian Ocean. The extreme turbulence associated with this "Retroflection" causes large rings and eddies to be shed into the South Atlantic. This so-called Agulhas Leakage is the primary mechanism of interocean exchange south of Africa and is recognized as an important source of heat and salt to the Atlantic Ocean, and the global THC.

The factors controlling the amount of Agulhas Leakage are poorly understood, but a long standing hypothesis is that north-south migrations of the Subtropical Front (STF) south of Africa play a role in regulating the Agulhas Leakage. The STF is defined as a zone of enhanced gradients of sea surface temperature and salinity. The goal of the research project is to reconstruct changes in the location of the STF south of Africa and compare that with variations in ocean circulation, specifically over the time period since the Last Glacial Maximum around 20,000 years ago. To do this, we will analyze samples from a suite of deep-sea sediment cores spanning the modern range of the STF. We will measure Mg/Ca ratios and oxygen isotopes of planktonic foraminifera fossils as geochemical proxies for sea surface temperature and salinity. The research will answer important questions about the changes in ocean circulation associated with Glacial Terminations, and therefore improve our understanding of rapid climate change.

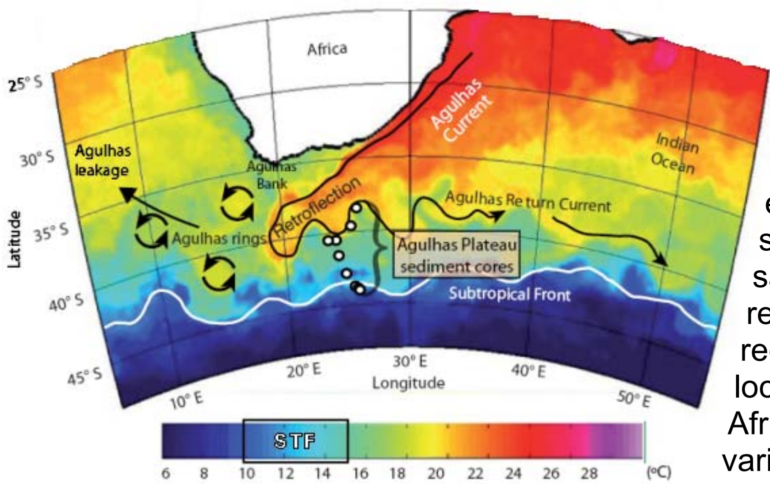


Figure modified from Beal et al. (2011) Nature 472

Analyses Required: This project will require sampling cores at the LDEO Sample Repository, sediment processing, identifying, counting and picking microfossils (specifically planktonic and benthic forams), sample preparation (including chemistry) and mass spectrometry.

Prerequisites: None, although some background in Earth Science and/or paleoceanography is a plus.

Thesis Mentor: Allison Franzese: franzese@ldeo.columbia.edu, 845-365-8918

Did Antarctica host ice sheets in the Cretaceous?

Background: Although Antarctica resided at high southerly latitudes throughout the Cretaceous (144-65 million years ago), our current understanding of the climate system suggests that it was ice-free during that time. Nonetheless, oxygen isotope ratios from low- and mid-latitude Cretaceous marine sediment cores and outcrops reveal large and rapid oxygen isotope excursions that are most readily explained by the waxing and waning of continental ice sheets. The intern selected for this research will test the hypothesis of ephemeral Cretaceous ice sheets on Antarctica by examining the provenance, texture, and isotopic composition of circum-Antarctic Ocean Drilling Program cores to identify possible temporal correlations between sea-level changes and/or cooling with the influx of detritus from Antarctica. Identification of the presence of continental ice sheets during a period of high atmospheric carbon-dioxide concentrations has large implications for understanding the ocean-atmosphere climate system, and for predicting environmental change in the future.

Analysis Required: This project will require sample preparation and Nd, Sr, O and other isotopic analyses of Ocean Drilling Program sediment cores collected from the Southern Ocean and/or other parts of the global ocean. Lab work will require 20 hrs/wk.

Prerequisites: There are no prerequisites, but coursework or previous research using geochemistry is an advantage.

Thesis Mentors: Sidney Hemming: sidney@ldeo.columbia.edu, 845-365-8417, Dave Barbeau: dbarbeau@geol.sc.edu, 803-777-5162 (note: Dave Barbeau will be in residence at LDEO starting in the summer. He will spend his sabbatical year at LDEO)

Can coral geochemistry be used to reconstruct salinity and temperature variability in the Indonesian Throughflow Current over the last 200 years?

Background: As the only low latitude interocean conduit, the Indonesian Throughflow (ITF) annually transports surface and thermocline depth water from the western Pacific Ocean north of the equator to 12°S in the eastern Indian Ocean and may be influential to global thermohaline circulation. Today, the net result of the ITF is a cooling and freshening of the Indian Ocean thermocline. In this project we will be using cores from the coral *Porites sp*. previously collected from Kapoposang in the southern Makassar Strait near S.W. Sulawesi and from Gili Meno in the Lombok Strait near Bali to develop near-monthly resolution coral oxygen isotope ($d^{18}O$) and Sr/Ca records in the late 20th century. The goal is to develop a calibration dataset for interpreting the paleo-record preserved in the same cores over the last 200 years. We recently completed monthly resolution analyses of a short section of *Porites* core from Kapoposang. These results demonstrate that the 2-3 p.s.s. salinity reduction during December-February is recorded in Makassar Strait coral $\delta^{18}O$. In addition, the preliminary data demonstrates that coral Sr/Ca variability accurately tracks the annual bi-modal SST cycle where SSTs peak in ~May and then again in ~November. The fact that coral Sr/Ca at this site records the subtle bi-modal SST changes attests to the fidelity of this tracer at this location. We will be working to replicate this remarkable result in other corals. The goal is to better understand salinity and SST variability in this critical strait in order to constrain ITF variability over the last several centuries. The ultimate goal is to better understand the dynamics and variability of this seasonal low salinity influx to the Makassar Strait so that we can understand it influence on the ITF.

Analysis Required: This project will be laboratory based at Lamont-Doherty. Student will learn the techniques for sampling coral cores and analyzing stable oxygen ($d^{18}O$) and carbon ($d^{13}C$) isotopes as well as strontium/calcium (Sr/Ca) ratios. Lab work will require 20 hrs/wk in the Geosciences building.

Prerequisites: None, but Interest in geochemisty and paleoclimate essential.

Thesis Mentor: Braddock Linsley blinlsey@ldeo.columbia.edu, 917-509-2484

Where is all the bad stuff? A study of deposition and distribution of sediments and contaminants in estuaries

Background: Detailed knowledge of the distribution and deposition of contaminated sediments in rivers and estuaries and related processes is essential for successful managing these systems. Over the last years detailed studies of several studies of the Hudson River estuary revealed significant variations of sediment deposition and the content of several metals (Zn, Pb) in different areas of the estuary.
As part of an ongoing project, this summer project will add to the existing database of sediment deposition and compare the new data with existing data to determine changed in deposition and contaminant composition. Differences in contaminant (metal) composition would indicate variation in sources and/or deposition processes. Depending on pending funding and field work timing this project could also investigate sediment contamination in the Long Island Sound and compare those with data from the Hudson River to analyze differences in contaminant composition and relate those to sources.

Analysis Required: The work will include analyzing selected sediment cores that are available in the Lamont core repository, determining the thickness of recent sediments in these cores, and integrating these results with the interpretation of seismic profiles from the area. Metal contents of the sediment cores will be determined using X-ray Fluorescence (XRF) spectrometry in the lab, interpretation of seismic data using a seismic interpretation software and data integration and analysis using GIS software.

Prerequisites: At least two semesters of college level chemistry or environmental sciences. Confidence in working with computers is preferred.
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Thesis Mentors: Frank Nitsche: fnitsche@ldeo.columbia.edu, 845-365-8746 ,
Tim Kenna: tkenna@ldeo.columbia.edu, 845-365-8513

Why did the tropical oceans cool 2 million years ago?

Background: Recent studies have shown that the temperature of the upper tropical ocean changed markedly during the past 10 million years. Today, there is a strong east-west asymmetry in sea surface temperatures (SST) along the equator (∆SST for the Pacific is ~8°C). Ocean drilling cores from the Atlantic, Pacific, and Indian oceans document that this modern east-west sea surface temperature (SST) asymmetry first appeared between 1.5-2.0 Ma. In the early Pliocene near 3.5 Ma, tropical ocean SSTs along the equator were nearly uniformly 27*C and this dramatically affected tropical rainfall patterns.

We still do not know why this change occurred near 2 Ma. Today the cold tropical SSTs are due to upwelling of deep cool waters that originate at the surface ocean in the middle latitudes. These mid-latitude waters are subducted, flow equatorward and upwell in the eastern tropical oceans due to surface wind stress and upwelling. One hypothesis for the absence of east-west SST gradient in the Pliocene is that the upwelled waters were also warmer because of the higher atmospheric CO2 at this time. This idea has never been tested directly because we have very few drill sites at the depth where this shallow, thermocline ventilation circulation occurs (~500m).

This project will test the idea that cooling of surface waters in the tropics was due to upwelling of cooler deep waters. Ocean drilling site 716B located at 544m water depth on the Maldives Ridge, N. Indian Ocean is an ideal site for this study. The shallow depth of this site allows reconstructions of subsurface temperatures from the oxygen isotopic composition of benthic foraminifera. Surface ocean temperatures will be reconstructed from the alkenone unsaturation proxy. Together, these measurements will directly test whether cooling of the surface tropical ocean accompanied cooling of subsurface waters. Ultimately these data will describe how global climate changed from the warm Pliocene to the colder Pleistocene glacial period.

Analysis Required: This project will require analysis of samples from a deep ocean sediment core. The student will prepare and analyze samples for alkenone-based temperature reconstructions (lipid extraction and analysis with gas chromatography). The student will also pick benthic foraminifera for stable isotope analyses. Undergraduate will be in charge of processing data and interpreting results. Lab work will require 30 hours/week.

Prerequisites: None although General Chemistry and Organic Chemistry would be helpful.

Thesis Mentors: Pratigya Polissar: polissar@ldeo.columbia.edu, 845-365-8400

Climate Dynamics of Victorian Holocausts

Background. Drought and famine across Asia in 1876-8 led to the deaths of tens of millions of people and have been analyzed in detail by Mike Davis in his 2001 book 'Late Victorian Holocausts: El Nino and the Making of the Third World'. Davis shows clearly how an initial climate perturbation fed through the British colonial economy and adherence to free trade principles to create mass starvation and mortality. The 1876-8 famine stands out as one of the most monstrous events during the history of western imperialism. According to Davis, prior droughts had not led to such mass mortality because of traditional systems of food security developed over centuries. It was the disruption of the food security system by the imperial economy that hence caused the mass mortality rather than particularly acute climate conditions. Until recently it has not been possible to examine the climate dynamics of the 1876-8 drought and famine. Rain gauge data covers the Indian subcontinent but is absent elsewhere before the past few decades. The Lamont Tree Ring Lab has now developed the Monsoon Asia Drought Atlas (MADA) with annually resolved maps of drought severity covering the past several centuries based on tree ring records from across Asia. In addition the new Twentieth Century Reanalysis (20CR) covers 1871 until 2008 and is a fully three dimensional atmospheric data set at daily resolution based on assimilation of surface pressure and sea surface temperature (SST) into the NCEP operational weather forecast model. In addition there are now multiple model simulations that cover the 1876-8 period with atmosphere models forced by observed SSTs.

Analysis Required: The project will seek to answer the following questions:
1. How unusual was the 1876-8 drought both in terms of severity in India and China and also in terms of the spatial extent? Was it unprecedented or within the range of climate variability that traditional societies had developed amidst?
2. What are the atmospheric circulation features of the 1876-8 drought? Can the drought be linked to the concurrent 1876-7 El Nino or were other factors at work including the influence of other oceans or internal atmospheric variability? Did droughts and famines in northeast Brazil and eastern Africa have the same cause as the Asian drought or were they separate events?
3. How common are pan-Asia droughts (like the 1876-8 one) that impact both the Indian subcontinent and major food producing areas of China? Are such droughts forced by particular configurations of SSTs or random synchronization of more localized droughts with distinct causes?

Prerequisites: A knowledge of the Ingrid climate data server and analysis software would be a plus as well as knowledge of standard methods in statistical analysis of spatial fields and time series e.g. time series analysis, linear correlation, regression analysis and multiple regression. Familiarity with climate dynamics is needed.

Thesis Mentors: Richard Seager seager@ldeo.columbia.edu, 212-666-5618, Ben Cook bc9z@ldeo.columbia.edu and Kevin Anchukaitis kja@ldeo.columbia.edu

Can we collect K/Ar evidence of ice stream behavior at Prydz Bay Antarctica?

Background: Understanding the dynamics of Antarctic ice at different time-scales through the Cenozoic is going to require the development and application of multiple proxies. The study of ice rafted detritus (IRD) provenance in deep ocean sediment cores gives insights into what sector(s) of the ice sheet were actively contributing icebergs at a given time. The study of terrigenous sediment compositions and textures in more proximal cores allows ground-truthing the provenance characteristics of important sectors, and further allows for a greater understanding of the local processes and their imprint on the sediment record. We have been studying the erosion history and glacial dynamics in the Prydz Bay sector of the East Antarctic Ice Sheet. This work is following up on previous discoveries in the area. For the summer intern project we propose to test the K/Ar system on fine grained sediments as a proxy for provenance and relative importance of physical versus chemical weathering effects.

Analysis Required: This project will require sample preparation and Ar isotopic analyses, elemental analysis, grain size distribution and SEM observations of Ocean Drilling Program sediment cores collected from the Prydz Bay sector. Lab work will require 20 hrs/wk.

Prerequisites: There are no prerequisites, but coursework or previous research using geochemistry is an advantage.

Thesis Mentors: Trevor Williams: Trevor Williams trevor@ldeo.columbia.edu, 845-365-8626; Sidney Hemming: sidney@ldeo.columbia.edu, 845-365-8417; Joel Gombiner: joelhg@gmail.com.

Does global thermohaline circulation slow down in a warm climate? An investigation of the long-term trend in water masses in Prydz Bay and adjacent regions.

Background: Antarctic Bottom Water (AABW) formation is a critical component of global thermohaline circulation. There is a great uncertainty about the AABW production in the Prydz Bay. Lack of winter observations is the main reason for the uncertainty. The water mass properties on the continental shelf and off the continental slope are critical factors for the formation of bottom water. In addition to obtain winter stratification of water column through deploying a mooring array on the Prydz Bay shelf, it is important to investigate whether long–term trends exist in the summer water mass properties on the shelf and off the slope. Any such long term trend would either increase or decrease the potential of the bottom water formation in the region. Proposed study here is to detect trends in the properties of the shelf water and Circumpolar Deep Water (CDW) in the region from historical CTD data that were usually taken during summers. We will also to explore any connections between the oceanic trends with long-term changes in atmospheric forcing. The result from this exploratory study would build a benchmark for our on-going field campaign and guide us on future research planning.

Analysis Required: We will start with establishing the data inventory. Currently, we have historical CTD surveys in the Prydz Bay region from Australian Antarctic Data Center archives. We will supplement Australia's data by the data from National Oceanography Data Center. All the data will be separated into three geographic groups: in the Amery Depression, on the shelf region north of the West Ice Shelf, and north of the continental slope and south of 64°S. For each group, the spatial variability within each cruise will be examined. If the spatial variability is too large, we would further divide the groups. Then seasonal mean of salinity and temperature profiles will be calculated below winter water on the shelf for each year when data are available. In the same way, we will calculate the seasonal mean salinity and temperature at T_{MAX} as well as mean salinity and temperature profiles off the slope. These mean profiles will be compared from decade to decade to detect long term trends. Uncertainty of the trends can be assessed by the standard deviation and range of the variability within each year.

Prerequisites: None, although knowledge of computer programming is a plus.

Thesis Mentor: Xiaojun Yuan, xyuan@ldeo.columbia.edu, 845-365-8820