How Does Volcanic Ash Affect Biological Productivity and Microfossil Alteration Outside the Pacific Gyres?

Background. Three cores taken outside the mid-Pacific Gyres (VM33-116-Bismarck Sea, VM28-309-Ryukyu Arc and RC14-44-Sunda Arc) contain dark colored foraminifera whose dark color is probably related to high concentrations of volcanic ash and consequent increased biological productivity. There are dark coatings and/or dark fillings of foraminifera within ash layers and normal, bright white foraminifera outside of ash layers. These findings are unexpected. Until now, the prevailing idea was that biological productivity would be increased by the iron in volcanic ash only if the sediment came from a core taken within an oceanic area of known low biological productivity like the mid-Pacific Gyres. This is called the iron fertilization hypothesis. At present, we require more accurate measurements of several parameters to better quantify the increase in biological productivity produced by volcanic ash: Ba, loss on ignition (LOI), $CaCO_3$ content, ash content, ash composition and biogenic silica content.

Proposed Research. After sampling, measuring magnetic susceptibility and grinding selected samples, the student will use X-Ray Fluorescence (XRF) to measure the trace element contents of bulk sediment and ash from one or more of the above cores both to document their content of Ba and also to determine other trace elements. The student will measure LOI on the bulk sediments: LOI is a proxy for organic matter content that is complementary to measurements of Ba. Compositions measured with the XRF will also be more accurate after LOI. The student will sieve samples as needed but will also examine already sieved samples for the appearance of foraminifera both within and outside of ash layers. We will use a scanning electron microscope and its X-ray analyzer to document the composition and morphologies of the dark/coated foraminifera and associated volcanic ash and the normal bright white foraminifera. One goal will be to assess the typical composition of the sediments both inside and outside of ash layers and thereby to assess changes in biological productivity produced by volcanic ash. We will send samples out for measurements of biogenic silica and will measure $CaCO_3$ content at LDEO. If time permits, we will also look at the grain size distribution of the ash as this may affect the biological availability of the iron in the ash. Another potential study would involve picking sufficient foraminifera outside of ash layers for analysis of their oxygen isotopic composition to better date individual ash layers using oxygen isotope stratigraphy. There are some microfossil extinction horizons within the cores- a student with a micropaleontology background could map the depths of first and/or last appearance of stratigraphic marker fossils.

Required Skills: The student need not have prior lab experience but should have an intense interest in the research. Strong organizational skills, patience and attention to detail are a plus.

Mentors: Dallas Abbott, dallashabbott@gmail.com
Karin Block, kblock@ccny.cuny.edu
Jiahua Wu, senxiaxiaxia@gmail.com

How Well Can We Date Marine Flooding, Solar Maxima and the Pollution History of the Hudson River?

Background: Two cores from the Hudson River, CD2-29A and LWB1-8 have sedimentation rates of ~1 cm per year since 1958. CD2-29A was taken off Manhattan and LWB1-8 off Yonkers, New York; 9 km and 29 km respectively above the Brooklyn Battery. Hudson River sediments contain intermittent layers of marine foraminifera up to Peekskill, NY, 64 km above the Brooklyn Battery. Some of these layers of marine foraminifera are associated with increased REE (rare earth element) content, especially Ce (enriched in seawater) and have higher wood contents. Both findings are consistent with the foraminifera-rich layers coming from incursions of seawater into the Hudson with maximum heights greater than ~1.7 meters above sea level at the Battery. The annual record of maximum seawater height at the Battery goes back to 1845. Before 1845, some major seawater floods are recorded but the history of flooding is not well known. In addition to increased REE contents associated with wood rich layers, we find some REE low layers that might result from solar maxima. From previous work on bogs, we know that bogs with high inputs of atmospheric material are enriched in REE by about a factor of 23-25 and in Ni/Cr ratio by a factor of 2.3 compared to bogs with low inputs of atmospheric material. Much of this atmospheric deposition is marine in origin but some comes from cosmic dust. This could mean that decreased REE contents and/or increased Ni/Cr ratios are diagnostic of an increased input of cosmic dust every 11 years during solar maxima, when high solar variability makes it more likely that cosmic dust will enter the Earth's atmosphere.

Proposed Research: The student will use X-Ray Fluorescence (XRF) to measure the trace element contents of Hudson River sediments both to document their content of heavy metals from pollution (e.g. Pb, As, Hg, Cd, Zn, Cu) and also to measure their Ni and Cr contents. (The ratio of Ni/Cr may be a proxy for cosmic dust input when overall Cr levels are low.) The student will measure LOI (loss on ignition) on the sediments as LOI is a proxy for the input of wood and organic matter that peaks during marine floods. XRF compositions will also be more accurate after LOI. The student will sieve samples as needed but will also examine already sieved samples for their content of foraminifera, wood and volcanic ash. We will use a scanning electron microscope and its X-ray analyzer to document the composition and morphologies of the foraminifera, wood and volcanic ash. The result will be a history of marine floods and heavy metal pollution, at the least at depths dated with Cs and at best with further dates from times of solar maxima.

Required Skills: The student need not have prior lab experience but should have an intense interest in the research. Strong organizational skills, patience and attention to detail are a plus.

Mentors. Dallas Abbott, dallashabbott@gmail.com
Ben Bostick, bostick@ldeo.columbia.edu
Jiahua Wu, senxiaxiaxia@gmail.com

How Does Variability in Environmental Conditions Influence the Form and Function of Arctic Tundra Ecosystems?

Background: The Arctic is one of the most rapidly warming regions on Earth (Ballinger et al. 2020), and thawing of large stores of permafrost carbon (C) could amplify global warming. Climate variability is also increasing, with more extreme weather events like heat waves, flooding, and storms. Arctic ecosystem responses to climate change and disturbance are variable in space and time. For example, less frequent but more intense storms might change the transport of C and nutrients on the landscape even if the mean precipitation is unaltered, and storms redirect nutrient inputs in lakes and alter lake productivity. Climate variability can have analogous effects on the movement, reproduction, and trophic interactions of wildlife species on land. We invite an undergraduate student to join the Arctic Long-term Ecological Research (Arctic LTER) research program to advance understanding of how variability in climate affects the form and function of tundra ecosystems.

Analysis Required: The student will collaborate with research mentors to identify, design and implement a hypothesis driven study to determine how variability in environmental conditions (i.e. air temperature, precipitation) affect C and nutrient cycling, vegetation form and function, and/or plant-animal interactions. While planning for this will be done during the Spring 2024 semester, study implementation (i.e. data collection and analyses) will take place over an 8-10 week period in (June/July/August) at Toolik Field Station, located in a remote location in Northern Alaska.

Physical Requirements: Applicants should be in good health, capable of rigorous outdoor activity, and prepared to live in a field camp where cooperation with others is essential, personal privacy is limited, and living accommodations are spare and simple.

Mentors:
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Bias-Corrected Climate Change Projections for Asia and South America

Background: The impacts of climate change are anticipated to present significant challenges for agriculture, water resources, infrastructure, and the livelihoods of billions of people across the globe. Projections generated by General Circulation Models (GCMs) are crucial for comprehending prospective climate changes over a region. Nevertheless, the coarse spatial resolution at which GCMs operate often limits the reliability of projections at regional and local scales. To enhance the accuracy of climate impact assessments, it is imperative to obtain precipitation and temperature projections at higher spatial resolutions. Additionally, biases in precipitation and temperature may arise from the GCMs' coarse resolution or model parameterizations.
This project attempts to employ bias-corrected climate change projection data derived from the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP) that are based on CMIP6 models. The objective is to analyze climate change information across Asia and South America under various warming scenarios.

Analysis Required: Here are the key components of this project;
1) Data collection (observational and five Models (HIST, Future Data)) for precipitation, and mean temperature (min and max).
2) Models' evaluation against observations during the reference period
3) Future changes with respect to the reference period for different scenarios and seasons
4) Summarize findings in a clear and accessible manner for publication.

Prerequisites:
- Understanding of fundamental principles of climate science is essential. Knowledge of CMPIP6 data is a plus.
- Proficiency in statistical methods and data science techniques is necessary. Interpreting results is critical.
- Proficiency and experience in one or more of the following: NCAR Command Language (NCL), Climate Data Operator (CDO), Grid Analysis and Display System (GrADS), Python, R

Mentor: Muhammad Azhar Ehsan, azhar@iri.columbia.edu
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What Was the Agulhas Current System Like During the Mid-Pleistocene Transition?

Background: The Mid-Pleistocene Transition (MPT) is the time interval from about 0.7 to 1.2 million years ago when Earth's climate transitioned from 41-thousand-year glacial cycles to higher amplitude 100-thousand-year glacial cycles. We are exploring the role of the Agulhas Current system through this important interval. The Agulhas Current is a major current flowing southward near the east coast of South Africa. A portion of it "leaks" into the Atlantic, bringing warm salty water from the Indian Ocean into the Atlantic circulation system. The extra salt is thought to have an important impact on the global ocean circulation and, consequently, global climate. Our previous studies have shown that sediments eroded from Africa and carried by the Agulhas Current system have a distinct geochemical signature that allows us to study the path and strength of the Agulhas Current system in the past. We are currently working with sediments from IODP Expedition 361 Site U1474 which is located near the beginning of the fully-constituted Agulhas Current, and Site U1479 which is located where the Agulhas leaks into the South Atlantic. Comparing these two sites allows us to study changes to the geochemical signature of sediments carried by the Agulhas Current, the Agulhas Current strength, and the Agulhas Leakage.

Analysis Required: This project will require sediment preparation and 40Ar* and other geochemical analysis (major and trace elements and perhaps radiogenic isotopes if time allows) of samples from IODP Site U1474. Lab work will require at least 20 hrs./ week. The student will work closely with at least one other undergraduate student.

Prerequisites: Experience in a chemistry lab (can be through coursework). Coursework or experience in Earth Science is a plus, especially paleoclimate or isotope geochemistry.

Mentors:

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What are the Magma Dynamics at Huaynaputina Volcano?

Background: Huaynaputina is a stratovolcano located in southern Peru. In 1600, it produced the largest eruption ever recorded in South America, with a volcanic explosivity index (VEI) of 6. The eruption generated up to 14 km^3 of tephra and a plume that reached heights above 30 km, causing worldwide weather disruption for a year after the event. The primary objective of modern volcanology is to comprehend the behavior of volcanoes, the causes of eruptions, and the parameters that led to their occurrence. Recent studies suggest that the style of eruption is closely linked to magma conduit processes and ascent parameters, such as magma ascent rate, volatile composition, and degassing rate. These parameters are also believed to be related to the vesicle population of volcanic ejecta. The aim of this study is to investigate various aspects of the petrology and eruption dynamics of the 1600 Huaynaputina eruption, through examining the texture of volcanic ejecta.

Analysis required: The student will analyze the texture of volcanic ejecta from three tephra layer deposits emitted during the Plinian phase of Huaynaputina's 1600 eruption. This study aims to investigate the nucleation timeline, magma ascent rate and pre-eruptive parameters through the quantification of the vesicle population within volcanic tephra. Lab work will involve sample preparation and polishing, acquisition and description of SEM high precision pictures, and H_2O-CO_2 FTIR measurements on glass and melt inclusions. The work will be divided into literature review, sample preparation, analysis and data processing.

Prerequisites: General petrology and lab courses. General knowledge about picture editors such as Gimp/ImageJ would be a plus.

Mentors:

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What is the Evidence from Reykjanes Ridge IODP Site U1562 for Variation of Northern Hemisphere Ice Sheets through the Early Pleistocene?

Background: Continental glaciers entrain sediment as they flow towards the ocean, and when they reach the ocean they calve to produce icebergs. These icebergs float on the ocean, following surface currents. As they move in the currents they melt along the path, dropping the sediment load onto the ocean floor. The sand and coarser fraction of these sediments are called ice rafted detritus (IRD). The Pleistocene is the geological epoch of Northern Hemisphere glaciations. Prior to 1.5 My , the periodic advances of Northern Hemisphere ice sheets were more frequent and less extensive than in the Late Pleistocene. The early Pleistocene history is important, but the records until now are less complete than for more recent events. Recently completed International Ocean Discovery Program Expedition 395 drilled several sites on the Reykjanes Ridge (the mid-Atlantic Ridge south of Iceland), to understand relationships between Icelandic hotspot development, ocean circulation and climate. Site U1562 is located near the active modern ridge. Based on the modern paths of currents, it is expected that icebergs that float over this site would likely have calved from Iceland or Greenland, although farther traveled icebergs from Scandinavia or Canada could get to this site in favorable conditions. As a step toward understanding the early Pleistocene record of climate and ice sheet variability, we seek to quantify the sand fraction of samples from Site U1562, to understand the environmental signal from fossil foraminifera and the flux of sediments deposited by icebergs. The composition of sand grains and granules from icebergs will provide information about their source location.

Analysis Required: This project will involve time series analysis of available data as well as new data to be collected from Site U1562. Lab work includes sample preparation to isolate the sand fraction, and using a microscope to identify and isolate benthic foraminifera, count the abundance of key foraminiferal species and sand grains melted from icebergs, from samples that come from the early Pleistocene portion (~1.5-2.5 Myr) of the site. Additional lab work will isolate the clay fractions from the fine sediment using settling methods for a subset of the samples. Lab work will average 30 hours per week, with remaining time spent on background reading and discussions about the project. Once the microscope work is completed, the main work will be synthesizing the new data with available data from the site and considering how to use these data to test hypotheses and extend our understanding of the Northern Hemisphere ice sheets' relationship with climate variability through the Pleistocene.

Prerequisites: Some understanding of Earth Sciences from coursework, and a keen interest in understanding how to use sediment records to "read" the past. The lab work requires attention to detail, and careful handling of samples.

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What is the Evidence from Natal Valley IODP Site U1474 for Variation in the Agulhas Current through the Early Pleistocene?

Background: The Agulhas Current is the largest western boundary current in the Southern Hemisphere, and it is intimately linked with regional rainfall patterns as well as global circulation patterns. It flows along the eastern coast of South Africa, fed by currents from across the Indian Ocean and along the Mozambique Channel. At the tip of South Africa the Agulhas Current retroflects back into the Indian Ocean, but leaks some eddies into the South Atlantic's Cape Basin. The added salt from these eddies is thought to be important for the formation of deep waters in the North Atlantic. International Ocean Discovery Program Expedition 361 drilled five sites in the greater Agulhas Current region with the goal of understanding changes in the Agulhas Current with global and regional climate variability and ocean circulation. Site U1474 is located in the Natal Valley, offshore Durban South Africa, and is at the headwaters of the fully constituted Agulhas Current. Multiple holes were spliced to yield a continuous sediment record for the past 5 million years. Shipboard measurements of physical properties, color, and post-expedition X-ray fluorescence scanning data are available to examine proxy evidence for past environmental changes. The early Pleistocene is a particularly interesting time as the Northern Hemisphere ice sheets waxed and waned on approximately 40,000 year cycles, and ocean circulation appears to have varied with a similar pacing. Stable isotope data from benthic foraminifera are necessary to refine the understanding of the depositional ages, as well as to characterize the deep water mass composition as a proxy for circulation changes, to better understand global connections between the Agulhas Current and other important players in the climate system.

Analysis Required: This project will involve time series analysis of available data from Site U1474. Lab work includes using a microscope to identify and isolate benthic foraminifera from samples that come from the early Pleistocene portion (~1.5-2.5 Myr) of the site. The samples will be weighed with a microbalance and sent to Cardiff University for stable isotope analysis. In the first 4 weeks, lab work will average 30 hours per week, with remaining time spend on background reading and discussions about the project. After the samples are sent away for stable isotope analysis, the main work will be synthesizing the available data from the site and considering how to use these data to test hypotheses and extend our understanding of the Agulhas Current's relationship with climate variability through the Pleistocene.

Prerequisites: Some understanding of Earth Sciences from coursework, and a keen interest in understanding how to use sediment records to "read" the past. The lab work requires attention to detail, and careful handling of samples.

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What is the Pacing of Northern Hemisphere Ice Sheet Growth and Retreat in the Early Pleistocene?

Background: Understanding the timing and magnitude of past ice sheet growth and collapse can give us insights into the future stability of our ice sheets globally. The expansion and intensification of Northern Hemisphere glaciations occurred about 2.6 million years ago. During this early period of northern hemisphere glaciations, globally integrated records of ice volume changes suggest that there was a glaciation every 41,000 years. However, there are high- latitude sediment core records that suggest ice sheets retreated and collapsed in the past more frequently than that. By studying deep-sea sediment cores taken close to current and past ice sheets, we can constrain the timing and pacing of past ice sheet collapse and big iceberg rafting events. During the summer of 2023, we sailed on the JOIDES Resolution sediment core drill ship with the International Ocean Discovery Program (IODP) in the North Atlantic Ocean. On this expedition, sediment cores were drilled close to Iceland and Greenland. These sediment cores contain signatures of past ice sheet growth and melting which go back to the onset of the intensification of northern hemisphere glaciations. Using these newly collected sediment cores, we will constrain the timing and pacing of northern hemisphere ice sheet stability.

Analysis Required: This summer project will be fully lab-based. For this project, we will be identifying and quantifying iceberg rafted debris in sediment cores, a proxy that informs us of when in the past there were large fluxes of icebergs and ice sheet decay. We will freeze dry and wet sieve sediment core samples starting at 1.6 million years ago at IODP Site U1564, south of Iceland. Then, we will work with the coarse fraction of the sediment under the microscope where we will quantify the iceberg rafted debris and pick out benthic foraminifera for oxygen isotope analyses.

Prerequisites: Some understanding of Earth Sciences from coursework, and a keen interest in understanding how to use sediment records to “read” the past. The lab work requires attention to detail, and careful handling of samples.

Mentors:
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How to Make a Volcano Disappear?

Background: Okmok Volcano, located on Umnak Island in the Aleutian Island Arc is a shield volcano known for its historic 43 BCE eruption that induced global climatic effects. Okmok last erupted in July 2008 in a powerful (VEI 4) phreatomagmatic eruption, which altered the landscape within Okmok's large caldera by forming a 300- meter tall tephra cone named Ahmanilix, and depositing a thick layer of fine-grained tephra inside the caldera and its flanks (Larsen et al., 2008). Since its formation just 15 years ago, the tephra cone has been exposed to the harsh weather typical of Okmok and the Aleutians. It has been eroding rapidly, and is now covered by deep erosional gullies, and is slowly slumping into the crater floor. The combination of the harsh high precipitation environment and the large amount of unconsolidated tephra at Ahmanilix makes it an excellent end-member test cases for studying the geomorphological evolution of volcanic structures in general. This includes a better understanding of lahars, the highly hazardous volcanic mass flows where fine-grained volcanic deposits are mobilized quickly by precipitation and can move as far as 100 km from the origin, inundating and damaging large areas.

Analysis Required: This project aims to measure the rate of erosional processes and outwash of Ahmanilix since the 2008 eruption using time-lapsed digital elevation models (DEMs). DEMs will be constructed from helicopter-based photographed supplemented with satellite-based publicly available DEMs of lower resolution. In Summer 2021, Summer 2022, and Spring 2023, we collected hundreds of photographs of the cone by helicopter-based aerial surveys in orbital flight path around the volcanic cones inside of Okmok caldera. These surveys provide a three-year high-resolution time series dataset that will enable us to calculate erosion rates of tephra cones inside Okmok and determine if there have been any significant morphological changes inside the
caldera. These photos will be processed using the Agisoft Metashape software to generate robust structure from motion (SfM) 3D models of the Ahmanilix, volcanic cone. In addition to the imagery, we gathered several bags of tephra samples from the base of Ahmanilix in September 2022. If interested, the student may conduct further analysis on the tephra samples to investigate the textural properties of these grains, including their size distribution, angle of repose, and angularity. By quantifying these characteristics, we hope to gain insights into macro erosional processes and the influence of the tephra on the cone's morphology.

Prerequisites: GIS experienced is required; Geology background and experience with photogrammetry is a plus.

Mentors:
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Did Icebergs and their Influence on Deep Ocean Circulation Cause the Most Dramatic Climate Changes of the Last Ice Age?

Background: The last ice age was punctuated by repeated abrupt climate changes that involved dramatic cooling of the northern hemisphere at times when much of southern hemisphere was warming. These climate shifts occurred at times of episodes of catastrophic iceberg discharge from the vast Laurentide ice sheet that covered much of North America, and the melting icebergs may have reduced northward heat transport by weakening the large-scale Atlantic meridional overturning circulation (AMOC). Although computer simulations consistently suggest it is possible, and this mechanism is widely favored as a potential explanation for these otherwise puzzling climate oscillations, some studies have argued that the bipolar temperature changes actually happened first, thus causing iceberg outbursts into the glacial ocean. A study site that is positioned near the boundary of the subtropical gyre and the subpolar North Atlantic holds great promise to contribute to resolving this puzzle. Paired measurements of two proxies for deep ocean circulation will be compared to proxy evidence for sea-surface temperature change and ice-drift in the central Atlantic. The selected intern will generate a paleoclimate record for the last ice age that can be combined with existing evidence to complete a record of variations in regional oceanographic climate conditions that can be compared to deep ocean proxies in the same sediment core. This in turn may help determine whether icebergs and melting ice initiated the climate changes, or were instead released afterward as glaciers grew in response to the abrupt northern cooling. What is needed is a sequence of evidence in the same sediments that can unequivocally clarify the roles of icebergs, glacial meltwater, ocean circulation and sea-surface temperature (SST) change. Simultaneous investigation of proxies for all of these processes in sediments from the selected study site may provide such insights.

Analysis Required: This project will involve hands-on investigation of marine sediments and their constituents, including microscopy and isotopic analysis of microfossils. The selected student will work in our shared sediment laboratory and microscopy laboratory in the New Core Lab at Lamont-Doherty Earth Observatory. Training and guidance will be provided by the McManus group for all procedures, which will use existing equipment including microscope, freeze-dryer, ovens, microbalance, sieves, and beakers. Lab work will require approximately 20 hrs./wk.

Prerequisites: None, although knowledge of basic oceanography and climate is helpful.

Mentor: Jerry McManus, jmcmanus@ldeo.columbia.edu, (845) 365-8722

How Did Past Ice Age Cycles Affect the Climate In the Pacific Ocean?

Background: The Earth has experienced repeated and extended episodes of global glaciation over the last two million years. These past climate changes increased in magnitude during the past million years, with sea level variations of more than 120 meters and large changes in regional temperature, in association with increases and decreases in the atmospheric concentration of carbon dioxide and other greenhouse gases. Although the climate variations are very well documented in ice cores from Antarctica and in sediment cores from the Atlantic Ocean, there is less detailed information available about oceanographic and climate changes in the Pacific Ocean throughout these glacial cycles. Sediment coring and ocean drilling by ODP and IODP has recovered long sequences of deep-sea sediments from a range of locations that hold the promise for insights into the Pacific response to global climate change, including variations in the tropical El Niño – Southern Oscillation (ENSO) phenomenon, and biological productivity and deep-ocean carbon storage in the North Pacific. This project is designed to allow a student to contribute to the body of knowledge that can help answer the question of how the Pacific Ocean varied through ice age climate cycles.

Analysis Required: This project will involve hands-on investigation of deep-sea sediments and sedimentary constituents, including microfossils, from one or more Pacific Ocean sites, and will include, sediment processing, microscopy and isotopic analysis of microfossils. The selected student will work in our shared sediment laboratory and microscopy laboratory in the New Core Lab at Lamont-Doherty Earth Observatory. Training and guidance will be provided by the McManus group for all procedures, which will use existing equipment including microscopes, freeze-dryers, ovens, microbalance, sieves, and beakers. Lab work will require approximately 20 hrs./wk.

Prerequisites: None, although knowledge of basic oceanography and climate is helpful.

Mentor: Jerry McManus, jmcmanus@ldeo.columbia.edu, (845) 365-8722

Can Hydration Reactions in the Lower Crust Act as a Source of Stress to Trigger Micro-earthquakes in Northeastern North America?

Background: Eastern North America is a site of a moderate level of intra-plate seismicity, with frequent instrumentally-recorded micro-earthquakes and infrequent large historic events, such as the 1663 Magnitude 7.3 Charlevoix (Quebec) earthquake. Most of the micro-earthquakes have faulting directions consistent with plate-tectonic movements, which are thought to imply that the North American lithosphere is critically stressed and everywhere close to failure. However, the epicenters of these micro-earthquakes are not randomly distributed, but rather are strongly clustered. Some areas exhibit high concentration (e.g. the Adirondack Mountains) and others exhibit low concentration (e.g. southern Vermont). Thus, we find plausible the notion that some process is acting to raise the stresses in areas of high concentrations, thus triggering earthquakes. The shallow mantle beneath southern New England contains a large region of very slow seismic velocities named the Northern Appalachian Anomaly (NAA) and hypothesized to be associated with a 400 km wide region of mantle upwelling. Although no volcanism is known to be associated with the NAA, small-scale Tertiary volcanism has occurred near a similar low-velocity body in Virginia, which is also associated with seismicity. Here we investigate the possibility that volcanic fluids such as H_20 and CO_2 from the NAA are causing hydration reactions in New England's lower crust, leading to volume increases that change the state of stress, and that drive some areas of the crust to failure, causing the earthquakes.

Analysis Required: The intern will be involved in testing previously-written Python-based stress-modeling code, applying it to northeastern North America, and comparing the results with the observed pattern of earthquakes.

Prerequisites: The intern should be willing to learn a little geophysics. Some prior exposure to general earth science, and especially to plate tectonics, and to the Python scientific programming environment would be helpful but is not required.

Mentor: Bill Menke, menke@ldeo.columbia.edu, (845) 304-5381
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What Are the Differences in Sediment Grain Size and Contaminant Distribution in Long Island Sound?

Background: Detailed knowledge of sediment dynamics and the related distributions of habitats and contaminated sediments in estuaries is essential for successfully managing these systems. The Long Island Sound Mapping Project is a collaboration between different universities from Connecticut, New York State (including Columbia, Stony Brook, and Queens College) as well as NOAA. The overarching goal is to provide a detailed benthic habitat analysis of Long Island Sound. This is an ongoing project that is mapping Long Island Sound in several different phases. In the summer 2024, our group will collect surface sediments and possibly sediment core samples in Western Long Island Sound. Planned analyses include grain size distribution, bulk chemical composition, and stable carbon and nitrogen isotopic composition. The new results will be compared with data from previous work. Of specific interest are differences in grain size distribution and contaminants, which can provide important insights into different sediment sources and how sediments are transported in the Long Island Sound system.

Analysis Required: Under supervision of the advisors, the student would participate in collecting sediment grab samples in Long Island Sound (depending on schedule), analyzing selected sediment samples and field descriptions, integrating the results, and comparing those with existing data from other parts of the Long Island Sound. Data analysis and integration will be done using Excel and GIS software.

Prerequisites: Confidence in working with Excel and potentially ArcGIS is preferred but not required.

Mentors:

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Tim Kenna, tkenna@ldeo.columbia.edu, (845) 365-8513

How Did Deep Ocean Circulation Change in the Eastern and Western Atlantic Basins Across Ice Age Cycles?

Background: The Earth has experienced repeated and extended episodes of global glaciation over the last two million years. These past climate changes were associated with changes in every part of the Earth System, including ocean circulation. Waters that bathe the abyssal reaches of every ocean basin are formed and derive their properties at only two locations on Earth, around Antarctica and in the marginal seas of the North Atlantic. North Atlantic Deep Water (NADW) is a major conduit of oxygen and anthropogenic carbon to the deep ocean, and its formation from the cooling of warm, northward flowing surface waters provides a substantial heat transport to high northern latitudes. As NADW spreads southward in the Atlantic, it fills both sides of the Mid-Atlantic ridge as separate but connected basins, with a greater contribution of southern-sourced water in the eastern basin. Here we will use proxies from deep sea sediments at multiple locations across both the eastern and western Atlantic basins to explore differences in the water masses over recent ice age cycles. The results will help provide a context for modern inferences that the production of NADW has diminished because of ongoing warming.

Work Required: This project is designed to allow a student to investigate physical and geochemical evidence for changes in deep ocean circulation in the eastern and western basins of the North Atlantic Ocean across recent Pleistocene ice age cycles. It will involve hands-on investigation of marine sediments and their constituents, including isotopic analysis of microfossils. The selected student will work in our shared sediment laboratory and microscopy laboratory in the New Core Lab at Lamont-Doherty Earth Observatory. Training and guidance will be provided by mentors McManus and Pallone for all procedures, which will use existing equipment including microscopes, freeze-dryers, ovens, microbalance, sieves, and beakers. Lab work will require approximately 20 hrs./wk.

Pre-requisites: None, although knowledge of basic oceanography and climate is helpful.

Mentors:
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How Did Atlantic Deep Ocean Circulation Change Across Ice Age Cycles?

Background: The Earth has experienced repeated and extended episodes of global glaciation over the last two million years. These past climate changes were associated with changes in every part of the Earth System, including ocean circulation. The water masses that make up the global deep ocean are salty, cold, and form in the high latitudes. These water masses spread throughout the oceans, driving the global thermohaline circulation. Atlantic deep ocean circulation is a critical arm of this global conveyor belt, which influences surface heat transport and ocean carbon cycling. Here we will investigate how Atlantic deep ocean circulation changed across past ice age cycles in the recent Pleistocene epoch. Scientific ocean drilling on the Iberian margin off Portugal in Fall 2022 recovered sediments at multiple water depths, bathed by deep waters that originate from the high latitudes of both the northern and southern hemispheres. These sediments are deposited at an exceptionally high rate, allowing for high-resolution, millennial scale reconstructions of abrupt climate changes in the Atlantic.

Work Required: This project is designed to allow a student to investigate physical and geochemical evidence for changes in deep ocean circulation at multiple water depths across Pleistocene ice age cycles. It will involve hands-on investigation of grain-size distributions and isotopic analysis of sedimentary constituents, such as microfossils, in deep sea sediments from International Ocean Discovery Program (IODP) Expedition 397 drilling sites on the Iberian Margin. The selected student will work in our shared sediment laboratory and microscopy laboratory in the New Core Lab at Lamont-Doherty Earth Observatory. Training and guidance will be provided by mentors McManus and Pallone for all procedures, which will use existing equipment including microscope, freeze-dryer, ovens, microbalance, sieves, beakers and automated grain-size analyzer. Lab work will require approximately 20 hrs/wk.

Pre-requisites: None, although knowledge of basic oceanography and climate is helpful.

Mentors:

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Where Does Boreal Wildfire Smoke Go?

Background: Under climate change, wildfires in Canadian and Siberian boreal forests are becoming increasingly common. Smoke from the wildfires is often lofted high into the atmosphere, where it can be transported over long distances. For example, in the summer of 2023, smoke from wildfires in northern Ontario and Quebec was transported to eastern US and Canadian cities, where millions of people were affected by record-breaking poor air quality. Boreal wildfire smoke also has the potential to amplify global warming and accelerate the consequences of climate change. Arctic temperatures are warming faster than anywhere else in the world. The melting of Arctic sea ice reduces global albedo, which in turn results in increased temperatures globally. Similarly, the melting of the Greenland ice sheet contributes to sea level rise. Recent research has found that the deposition of smoke on sea ice and ice sheets increases melting rates, and the most recent report from the International Panel on Climate Change identifies warming from boreal wildfire smoke as a source of substantial uncertainty in the climate system.

Analysis Required: This project will identify and analyze the transport pathways and remotely sensed aerosol optical depth anomalies associated with boreal wildfire events. Using the MODIS fire product (a satellite data product), we will identify major boreal wildfire events in recent years, and use remotely sensed satellite observations (MODIS and CALIOP) and forward models to identify the extent of boreal wildfire smoke transport. On average, the intern will spend 30 hrs./week doing computational analysis, with additional time for literature reviews, writing, and discussions with mentors. In particular, the mentee will have opportunities to develop or deepen their analytical and computational skills, with an emphasis on learning the analytical techniques commonly used in climate science.

Prerequisites: Coursework in Climate/Earth Science, Physics, Chemistry, Statistics or other climate-relevant field, with interest in learning more about climate change. Some coding experience (e.g. Matlab, Python, R) is preferred, but not required.

Mentors:
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How Will Environmental Change Impact Oyster Shell Calcification and Function?

Background: As global climate change accelerates, the accurate prediction of biological responses to climatic and anthropogenic disturbances is crucial for mitigating potential damage to the biosphere. Large-scale assessments of the processes shaping biological responses in real-world ecosystems are rare but essential for establishing the theoretical baseline needed to forecast the extent of species responses. This is particularly critical for foundation species with both high climate sensitivity and key ecological roles. However, our ability to predict the responses of species and ecosystems to multiple stressors is severely constrained by models mostly derived from controlled experiments and small-scale field studies.

Organisms that produce calcified shells and skeletons are expected to encounter significant challenges in rapidly changing environments. The eastern oyster *Crassostrea virginica* is a calcifying foundation species, producing intertidal reefs that once were a dominant structural and ecological component of many estuaries in the Northwest Atlantic. Oyster reefs offer essential ecosystem goods and services, promote biodiversity, enhance water quality, and protect shorelines from storms and sea-level rise. Nevertheless, *C. virginica* reefs have experienced a drastic decline due to climate and anthropogenic impacts, prompting extensive conservation and restoration programs. Calcareous shells play crucial roles in providing support and protection for oysters, creating reef habitats that support marine communities and estuarine ecosystems. While climate alterations are known to affect oyster calcification and survival, their consequences on the oysters' shell production, their susceptibility to predation, and consequently, the structural integrity of reefs in natural systems across climate regions, remain a significant research gap.

Analysis Required: The work will quantify and model large-scale geographic patterns of oyster shell structure, calcification, and morphology across latitudinal and predation gradients. This project will analyze shells from wild and cultured oyster populations collected from Canada, New England, Florida and Texas, covering different ecoregions in the Northwest Atlantic. Laboratory work includes oyster shell samples preparation, collection of morphological shell data, shell sectioning and polishing, and microscopy. Laboratory work will average 25hrs./wk., with the rest of the time being focused on datasets organization, data analysis, and literature review. The student will also have the opportunity to take part to a summer sampling and monitoring field day in collaboration with the Billion Oyster Project.

Prerequisites: Background in environmental sciences or marine biology. The candidate should be methodical, well-organized with excellent time management and interpersonal skills. Laboratory experience is not required but desirable, and the candidate should feel comfortable working in a collaborative laboratory environment. The candidate should feel comfortable commuting to the Lamont-Doherty Earth Observatory for all laboratory work.

Mentor: Dr. Luca Telesca, ltelesca@ldeo.columbia.edu, (845) 365-8738

How Did Sediment Supply Change With Climate During the Pleistocene in Antarctica?

Background: Glacial-marine sediments from the continental margin of Antarctica and in the Southern Ocean provide important information about past depositional environments and the evolution of ice sheets, thereby archiving past climatic and oceanographic changes. These sediments have a wide range of particle sizes ranging from microns to tens or even hundreds of millimeters, which are transported from the Antarctic continent to the ocean through different transport processes, such as meltwater, iceberg and sea ice rafting, surface and bottom currents and winds. Icebergs carry the entire range of particle sizes, but they are unique in their ability to bring coarse grains to the deep ocean beyond the reach of downslope flows. For this reason, coarse detritus (>250 μm) is typically studied to characterize ice-rafting from melting icebergs. In contrast, silt-sized sediments (<63 μm), in addition to being transported by icebergs, can also be carried by deep-sea currents, gravity currents and wind to the pelagic realm. Therefore, grain size is an important parameter used to reconstruct past depositional environments and ocean circulation.

This research focuses on the Pleistocene sediments retrieved from Ocean Drilling Program (ODP) Site 694 during ODP Leg 113 in the Weddell Sea. The targeted cores are composed of interbedded hemipelagic and fine-grained turbidite sediments with varying amounts of ice-rafted debris (IRD), which may be associated with glacial-interglacial cycles. To better understand the variations in sedimentary environment and constrain the timing of the changes and their associations with climate proxies, a higher-resolution sediment analysis is necessary. The aim of this project is to measure the relative proportions of different-sized particles in these sediments and the temporal change during the interval, and to interpret the sedimentary processes that deposited them and the implied environmental changes.

Analysis Required: Lab work will be conducted at LDEO, and includes sediment freeze-drying, sieving, weighting, density separation with heavy liquids and IRD counting under the microscope. Lab work will average 30 hrs./wk., with the rest of the time being focused on core observation of X-ray images, data processing and analysis, literature reading, etc. Interested interns may have the opportunity to learn about mineral separation and isotopic analyses, but it is not a requirement for the project.

Prerequisites: We are seeking a responsible and patient student who has an interest in lab work. A background in Earth Science with laboratory experience is preferred.

Mentors:

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