How Did the Younger Toba Ash Affect Biological Productivity and Alteration of Microfossils?

Background. The younger Toba eruption was one of the two largest volcanic eruptions on Earth during the last 80,000 years. Two cores containing the younger Toba ash (RC14-44 and RC14-37) contain dark colored foraminifera with apparent diagenetic coatings and/or fillings within ash layers. Outside ash layers the foraminifera are bright and white in color. We attribute these changes in colors of the foraminifera to iron fertilization from the volcanic ash. In the thicker ash layer in RC14-37, we also see higher S at the top. This may be due to deposition of sulfate aerosol derived from the Toba ash. The S content of the Toba ash is disputed. Estimates of its S emission range from 70 to 660 Tg of SO_2. We wish to better quantify the increase in biological productivity and increase in S produced by volcanic ash in general and the Toba ash in particular by measuring Ba, X-ray diffraction assessment of clay mineralogy and dust, $CaCO_3$ content, ash content, biogenic silica and isotopic measurements on foraminifera inside and outside the Toba layer.

Proposed Research. The student will use X-Ray Fluorescence (XRF) to measure the trace element contents of bulk sediment and ash from both of the above cores both to document their content of Ba and also to determine other trace elements. The student will measure ∂C13 on foraminifera within the ash layer: ∂C13 is a proxy for biological productivity that is complementary to measurements of Ba. The student will sieve samples as needed but will also examine already sieved samples for 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 dark foraminifera and associated volcanic ash. The 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 and the overall S content of the 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 part of the project would be to pick sufficient foraminifera outside of ash layers for analysis of their oxygen isotopic composition to better date individual ash layers using oxygen isotope stratigraphy.

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

What Are the Best Methods of Finding and Verifying Oceanic Impact Craters?

Background: We have samples from four vibracores taken in the Gulf of Carpentaria. Our sieved samples contain magnetic, quench textured spherules. Many have tektite like shapes. All are geologically young. Spherule abundance and magnetic susceptibility peak in the top 10 to 20 cm of these cores. In all cores, there are lithified aggregates that contain spherules and other minerals. In some cases, the spherules appear shot into rock and the groundmass is Pb and C rich. This may represent pre-existing basement that was excavated by an impact event. The student will use an XRF and an XRD to map the composition and mineralogy of selected size fractions versus depth in the top 20 cm of each of the four cores. The goal is to see how bulk composition and mineralogy varies with size fraction and depth in the spherule bearing layers. Because of their tektite like shapes and the presence of spherule aggregates, the magnetic spherules are candidates for impact ejecta from an oceanic impact. However, most meteorite ablation spherules do not contain significant Ni- either the NI is vaporized or it migrates into so called nuggets within the spherules. We found hundreds of magnetic spherules but only one spherule was 100% Ni. If these are impact spherules originally derived from an Fe-Ni meteorite, significant Ni should be present somewhere in the sediment. We will look for this Ni and will also use the most recent satellite altimetry (2025) to search for source crater candidates. Our research will provide insight into the source(s) of the unusual quench textured spherules.

We have also developed a scheme for looking for impact craters using the core library at LDEO. The student will spend the first week examining LDEO cores in which metamorphosed rock is recorded and/or in which the core pipe was bent in areas with thick, unconsolidated sediments. Larger impact events produce impact melt. Thin layers of impact melt would not necessarily be detectable in seismic profiles nor would smaller craters (<~20 km in diameter) be detectable with satellite altimetry. One way to find crater candidates is to look for the metamorphosed and hardened bottom sediments produced by contact with hot impact melt. In areas of thick marine sediment, impact melt should have a different composition than basaltic basement. We can obtain a preliminary analysis of prospective impact melt using the LDEO XRF. If we find good candidates for impact melt, the student will compile geophysical and core data to see if an impact crater might be present in this location.

Prerequisites: Strong interest in geology, geochemistry, geophysics and extraterrestrial impacts. High tolerance for uncertainty and intense curiosity.

Mentor: Dallas Abbott, dallashabbott@gmail.com

How Has Atlantic Deep Ocean Circulation Changed Since the Last Glacial Maximum?

Background: The Earth has experienced repeated and extended episodes of global glaciation over the last two million years, the last of which reached its peak approximately 20,000 years ago. 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 has changed since the last glacial maximum (LGM), through deglaciation, and into the Holocene. Scientific ocean drilling on the Iberian margin off Portugal in the Fall of 2022 recovered sediments at multiple water depths, bathed by deep waters originating from the high latitudes of 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.

Analysis Required: This project is designed to allow a student to investigate physical and geochemical evidence for changes in deep ocean circulation since the LGM. It will involve hands-on 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 Arellano for all procedures, which will use existing equipment including a 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.

Mentors: Apollonia Arellano: arellano@ldeo.columbia.edu
Jerry McManus: jmcmanus@ldeo.columbia.edu

What Is the Structure of the Ocean Barrier Layer Depth in the Southern Ocean?

Background: Ocean stratification, determined by the combined effects of temperature and salinity on density, is a key driver of processes such as ocean currents, heat transport, and carbon storage. In the upper ocean, the mixed layer lies closest to the surface, with relatively constant temperature and salinity due to active mixing. Beneath the mixed layer often lies the barrier layer, characterized by a temperature maximum and rapid salinity changes. While the mixed layer and its seasonal variability have been well-studied in the Southern Ocean, the barrier layer remains understudied despite its critical role in regulating heat exchange between the atmosphere and ocean. In the mixed layer, heat exchanges with the atmosphere are relatively easy due to homogeneous density and unimpeded mixing. In contrast, the barrier layer's rapid salinity-driven density changes hinder mixing, effectively trapping heat below the mixed layer and modulating heat release to the atmosphere. Understanding barrier layer properties is thus essential for assessing ocean-atmosphere interactions and the effects of climate change in the Southern Ocean—a region pivotal to global climate regulation. A study by Pan et al. (2018) analyzed the Southern Ocean barrier layer using Argo float data from 2000–2015. However, the dataset excluded more recent observations, despite significant increases in the number of Argo floats and climate changes in the Southern Ocean over the past decade, such as shifts in sea ice extent.

Analysis Required: This project will analyze Southern Ocean barrier layer properties using an expanded Argo float dataset from 2000–2024. Specific objectives include (1) Loading and processing Argo temperature and salinity profiles from the Southern Ocean, (2) Calculating barrier layer depth and evaluating its regional and seasonal variability, and (3) Identifying trends and changes in barrier layer properties over the last two decades. The analysis will be conducted in Python, leveraging libraries such as xarray, numpy, and matplotlib. Tasks will include data cleaning, visualization, and statistical analysis of barrier layer properties across spatial and temporal scales.

Prerequisites: Coursework and/or relevant experience in college-level physics, calculus, and Python are encouraged. Coursework relating to oceanography, the climate system, and/or fluid dynamics may be useful, but are not required.

Mentors: Dhruv Balwada, dbalwada@ldeo.columbia.edu; Andrew Fagerheim, afagerheim@ldeo.columbia.edu

Does Arctic Warming Impact the Reproductive Success of Songbirds Migrating to Northern Alaska?

Background: The Arctic is warming three to four times fast than the rest of the planet, with significant biotic responses. Feedbacks among different levels of biological organization are key to understanding how climate change will shape Arctic ecosystems of the future. For example, every spring, millions of songbirds migrate from all over the world to breed in northern Alaska, and as such they rely on local tundra ecosystems to shelter and feed their young. While warmer climates may increase productivity of the vegetation (e.g. taller willow shrubs) and insect (e.g. more beetles) communities upon which they depend, feedbacks or constraints on their ability to adapt to changes could also have negative consequences that would ultimately affect the reproductive success of songbirds.

Work Required: We invite an undergraduate student to join the Evolving MetaEcosystems Institute (EvoME Institute) to specifically help our team to advance understanding of how Arctic warming is changing vegetation and insect communities in ways that may impact the reproductive success of songbirds that migrate to northern Alaska to breed each spring. To this end, the student will collaborate with research mentors to determine how feeding behavior of breeding songbirds is affected by dynamics in plant and insect productivity to ultimately impact their reproductive success (i.e. the number of chicks that fledge per nest). While planning for this will be done during the Spring 2025 semester, study implementation (i.e. data collection and processing) will take place over an 4-6 week period in June/July at Toolik Field Station, located in a remote location of northern Alaska. While in Alaska, the student will work as part of a small team to search for songbird nests in the tundra, deploy temperature sensors and cameras in/adjacent to the nests (used to quantify foraging behavior) and monitor the nests on a near-daily basis (to determine the number and hatch date of eggs, as well as the number of chicks that survived to fledge (i.e. reproductive success) from each nest. Although the student will work primarily on the songbird part of EvoME's field team, they will also work alongside and in collaboration with students and researchers working on other, strongly related parts of EvoME.

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. Student should have a source of stipend. Other expenses will be covered.

Mentors: Natalie T. Boelman, nboelman@ldeo.columbia.edu
Ian Shuman, ins2109@columbia.edu

What Are the Markers of Photosynthesis In the Rock Record?

Background: Few events have changed the Earth as has photosynthesis, which produced oxygen and created the atmosphere that supports modern life. Although we know a lot about when oxygen became abundant in the atmosphere (about 2.5 billion years ago), photosynthesis had to precede it. Increasingly, recent evidence obtained from microbialites, which are “reefs’ of microbes that populated shallow seas long ago, suggests that early photosynthesis was anaerobic, and evolved much earlier, and that it produced “oases” of local oxidation within an anaerobic ocean that persisted until the ocean and atmosphere were more oxidized. Studying this period in Earth’s history is complicated because there are few rocks dating from this period, and even fewer that have not been altered sufficiently to destroy these microbialites. This project would involve studying a unique and relatively unaltered core from the Moodies group in South Africa (~ 3.4 billion years old) using a comprehensive set of geochemical methods to identify mineral signatures of photosynthesis. We expect to find a series of oxidized mineral products that could only be produced through endergonic processes (which require energy) like photosynthesis. We also will study alteration in detrital minerals that are transported into the sediments from the land surface to understand more about conditions that were present on the continents and in rivers that transported that material to the shallow ocean.

Analysis Required: This project will analyze rock sections with a series of analytical methods ranging from X-ray Fluorescence microscopy, X-ray absorption spectroscopy, Raman and IR microscopy. These tools are powerful probes of mineral structure that can be used on thin sections collected from the cores where additional data like iron and other isotopic composition is known and the depositional environment of the system is understood from detailed stratigraphic analysis. Lab work will average 30 hr./wk., with the rest of the time being focused on data analysis, literature review, and group activities etc. We also plan to compare our results to data from a core collected in New York City.

Prerequisites: General chemistry and lab courses are required. Additional chemistry with interests in biological and environmental issues would be a plus.

Mentor: Benjamin Bostick, bostick@ldeo.columbia.edu, 845-365-8659

What are the Connections Between Surface Water Hydrology and Drinking Water Quality in Native American Communities?

Background: Water is a precious resource that sustains life. High quality drinking water sources have sufficient water quality (clean water) and quantity (enough water). Unfortunately, billions of people rely upon water sources that are of dubious quality, and most water use rates exceed supply. More than 200 million people globally, and millions in the US, have drinking water arsenic levels that exceed the maximum contaminant level set by the EPA. This water is potentially unfit for consumption. This contamination is widespread and heterogeneous, and we rely on private, optional well testing to measure the water quality in a given well. Most wells are unmeasured, and as a result, most people are unaware if they are exposed to arsenic. This lack of testing makes it nearly impossible to take corrective actions to improve water quality. This research project would characterize water quality in Native American communities in the Northern Plains of the US that are significantly impacted by arsenic and uranium. We will use a combination of existing field data, remote sensing and hydrology to examine the connection between surface and groundwater hydrology and elevated levels of arsenic and uranium in the water. We expect to find that natural arsenic and uranium contaminate groundwater as it reacts with rocks and the water becomes more saline. This project will involve some lab work with new samples to characterize water samples, and extensive coding (primarily in R) to use the combination of existing data and remote sensing data to develop predictive models that estimate water quality regionally at the fine scales needed to inform action. This project also could involve field work for water sampling and water quality assessment if it is possible to do so within the summer program.

Analysis Required: This project will analyze water samples using electrodes, ion chromatography, and inductively coupled plasma mass spectrometry. It will involve considerable spatial analysis as well, to develop maps of the data, and predictive models that use the sparse data that is available in rural communities that are involved in this research to understand places that have received even less attention. These models will be created in R (or Python). Lab and computer work will average 30 hrs./wk., with the rest of the time being focused on data analysis, literature review, and group activities etc.

Prerequisites: General chemistry and GIS or remote sensing courses are ideal, coding experience helpful, interests in biological and environmental issues would be a plus.

Mentors: Benjamin Bostick, bostick@ldeo.columbia.edu, 845-365-8659, Steve Chillrud, chilli@ldeo.columbia.edu, 845-365-8893

Does the Leithsville Formation Preserve Evidence for High Latitude to Low Latitude Wandering of Laurentia During the Lower to Middle Cambrian?

Background: The Center for the Investigation of Native and Ancient Quarries supported the geological mapping of 7 geological quadrangles in New York and New Jersey. The purpose was to generate a chert and litho/biostratigraphy for the investigation of the Cambrian-Ordovician Kittatinny Supergroup (LaPorta, 2009). This research led to the subdivision of the Kittatinny Supergroup into eight formation and eighteen member subdivisions (LaPorta, 2009). The geologic mapping collected information that might serve as proxy data for paleoclimate inferences for Laurentia during the Lower to Middle Cambrian. These data include such features as faunal changes (stromatolites) and stratigraphic/sedimentological features, (nodular cherts), which are hypothesized to be climatically forced. Additional field research is required to ascertain if such data supports Laurentian tectonic movement from higher to lower latitudes during the deposition of the Cambrian Leithsville Formation.

Analysis Required: This project will require field work in Sussex County, New Jersey and Orange County, New York, collecting stratigraphic/sedimentological and faunal data from the chert bearing carbonates of the Cambrian Leithsville Formation and its attendant members (LaPorta, 2009). It is estimated that approximately 120 hours of field time will be required. Office/lab work will consist of updating previous versions of the Hamburg 7.5’ Quadrangle (LaPorta, 2009) and extending geologic map data into contiguous quadrangles. Additionally, microscope thin section analyses will be conducted to discern micro, as well as macro, invertebrate fossil and diagenetic sedimentological information required to support climate inferences. Analysis is estimated to require 200 hours. A final report and presentation of findings is expected. The write up will consume about 80 hours of time. Student field work would occur in June and July of 2025. Laboratory analysis and write up would occur during non-field time periods.

Prerequisites: Grades of A- or higher in stratigraphy, biostratigraphy, mineralogy, petrology and structural geology. Students who have completed a geological field methods and mapping course are preferred, but it is not a requirement. Knowledge of the Brunton compass, hand-sample mineralogy, petrology, invertebrate paleontology, and office methods in structural geology would be helpful. This project would be ideal for students interested in Appalachian tectonic stratigraphy and structural geology, and enjoy being out in the field.

Mentors: Philip C. LaPorta, Ph.D., pcl2125@columbia.edu;
Margaret Brewer-LaPorta, Ph.D. mcblaporta.cinaq@gmail.com,
Scott A. Minchak, sminchak.cinaq@gmail.com

Building a Novel Inversion Method for Ice-Penetrating Radar Data

Project Description: Phase-sensitive radio echo sounders are used to measure changes within ice sheets. The ice-penetrating radar operates by measuring two-way travel times to reflectors within the ice. Repeat measurements at the same location allow determination of vertical deflection of englacial layers – a measure of ice deformation. From these measurements, glaciologists can determine strain rates and compaction rates, and relate these observations to processes that describe ice-sheet motion, i.e. rheology of ice and densification mechanics of firn (snow to ice transition).

Near-surface layers of ice compress at a different rate than layers deeper in the ice column. This compaction of firn can skew ice-sheet volume estimates, but compaction rates can be constrained by ice-penetrating radar observations. However, the two-way travel time of the radar signal varies depending on the firn density, so we need inverse methods to infer compaction rates from apparent changes in the radar observations. Existing inversion methods try to find density profiles and ice velocities that satisfy both the radar observations and physics, but there is no consensus on the models used in these methods.

Currently, a novel method using physics-informed neural networks is being developed to infer ice deformation from phase sensitive radio observations. This method uses a neural network's ability to solve differential equations, and may avoid some of the artifacts that arise in traditional methods. However, this neural network method has not been adapted to include firn compaction. This project will investigate different firn compaction models, and modify an existing neural network framework to include the physics of firn.

Analysis Required: First, the student will review different firn models while getting acquainted with neural networks. They will apply existing models to phase sensitive radio data. The student will then modify the provided neural network code to represent firn physics. The student will be asked to highlight how the inclusion of firn impacts inversion results, and time permitting, the student can estimate firn compaction rates.

Prerequisites: Experience programming with python is required. Knowledge of differential equations is preferred. Interest in cryospheric sciences and/or machine learning is a plus.

Mentors: George Lu (glu@ldeo.columbia.edu), Jonathan Kingslake (j.kingslake@columbia.edu), Andrew Hoffman (aohoffman@ldeo.columbia.edu)

How Did Past Ice Age Cycles Affect the Pacific and Atlantic?

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 the global ocean. Recent IODP drilling expeditions have recovered high-quality sediment sequences that combine with legacy materials from Ocean Drilling to provide ideal opportunities for research into Earth's past. This project is designed to look at the impact of past abrupt changes on the cryosphere, ocean circulation, and the Earth's climate, with a particular focus on the similarities and contrasting behavior of the Atlantic and Pacific Oceans. It involves piecing together evidence about catastrophic iceberg discharges, changes in the large-scale system of deep ocean currents, and dramatic shifts in surface ocean environmental conditions in various parts of the globe. The intern will help sample, process, and analyze deep-sea sediments from repositories of the international drilling program. Samples will be from cores recovered from the Atlantic and Pacific Oceans, in the northern and southern hemispheres and the tropics. The intern will help with processing tasks: freeze-drying, weighing on a microbalance, wet-sieving using a semiautomated system, oven drying and re-weighing of the coarse material, settling, and decanting and air-drying of the finest material. In consultation with Dr. McManus, the intern will select a subset of the samples for detailed analysis of the sediment composition, microfossil abundance and assemblage, grain size distribution, and abundance of iceberg deposition at high latitudes and dust deposition in the tropics. These analyses will include a combination of automated bulk measurements and observations using a binocular microscope. All necessary training will be provided. The intern will then interpret the results, with guidance from McManus.

Work Required: This project is designed to allow a student to investigate physical and geochemical evidence for changes in deep ocean circulation in the Atlantic and Pacific Oceans 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 mentor McManus 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.

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

Mentor: Jerry McManus, jmcmanus@ldeo.columbia.edu

Constraining Pliocene Arctic Climate Variability With a Robust Magnetic Stratigraphy

Background: There are few high resolution reconstructions of climate variability during the Pliocene Epoch (5.3 to 2.6 Million years ago) from the High Arctic, in part due to the limited number of long marine drill records and chronological challenges. The Pliocene, as a time that had high atmospheric CO_2 concentrations similar to today, may help to improve our understanding of how the Arctic will continue to change in the coming centuries. New drill cores recovered during the International Ocean Discovery Program (IODP) Expedition 403 recovered exceptional stratigraphic sequences from the Fram Strait with high accumulation rates (>10 cm/ kyr) extending to the latest Miocene around 6 Ma. These records show dynamic paleoenvironmental change in the concentration of iceberg rafted debris, bioturbation, and sediment bulk composition. However, limited fossil preservation and complex magnetic mineral assemblages limit dating of these sequences using traditional biostratigraphic and magnetostratigraphic methods. Yet, developing methodology may allow us to establish a robust paleomagnetic record, providing a new opportunity to study Pliocene Arctic climate trends, rhythms and events in a global context.

Analyses Required: This project will characterize the magnetic properties of Arctic sediments from ~80° N recovered during IODP Expedition 403, which contain a mixed magnetic mineral assemblage including detrital iron oxides, like magnetite (Fe_3O_4), and authigenic iron sulfides, like greigite (Fe_3S_4). Work will take place in the LDEO Paleomagnetics Lab. The first three weeks will involve subjecting samples to a range of applied magnetic fields (0-1000 mT) and thermal treatments (0-700° C) to assess approaches that preferentially demagnetize the iron sulfide hosted magnetizations while preserving the iron oxide hosted magnetizations. The student will work closely with Reilly to interpret the data. During the second three weeks (4-6), we will apply these findings to oriented paleomagnetic samples with the goal of resolving the Pliocene 'lower Mammoth' magnetic reversal to constrain the timing of the M2 glaciation and mid-Pliocene Warm Period. The final phase will be to synthesize results and summarize the findings.

Prerequisites: Coursework in historical geology, sedimentology and stratigraphy, and/or Earth Science lab courses are a plus. Applicants should have an interest in paleoclimate, paleoceanography, and/or polar region climate change.

Mentor: Brendan Reilly, breilly@ldeo.columbia.edu

How Does Meltwater Affect the Flow of Glacier Ice?

Background: Glacial ice reacts to gravity by moving, or flowing, via the rearrangements of its small-scale materials into energetically favorable orientations. The rate of flow determines how quickly ice moves to warmer regions closer to the sea, where it is able to break off or melt, affecting sea level rise. However, we do not understand the rate of ice flow very well, especially when small amounts of meltwater are present within the glacial mass. Water seems to make ice flow faster, but it is not yet clear if this is because water makes intracrystalline ice deformation more efficient, or if the water itself is able to deform in a way that encourages sliding of ice crystals. This means that our estimates of sea level rise are highly uncertain, especially as a warming climate may lead to increased amounts of internal glacial meltwater that may accelerate ice flow even further. This project will work towards a better understanding of the flow of partially melted ice via laboratory experiments. We will use custom ice deformation machines to compress lab-made ice samples that contain a small degree of melt, then examine how the microstructural orientations of both solid ice and meltwater inclusions evolve as stresses change. This work will have strong societal impact, as it will affect the glacial flow laws used to predict sea level rise. The student will gain expertise in experimental laboratory techniques and hands-on glaciology, and can expect to present results from this internship at a national or regional geoscience meeting in 2025 - 2026.

Analysis required: The intern will work with both experimental and computational methods. The experimental work will include creation of starting material and setup of ice compression tests that examine the impact of melt over a wide range of stress and strain conditions, and possibly melt fractions. The intern will then work with the mentors to acquire cryo-SEM images needed to carry out microstructural analysis. The computational work will include segmentation of images to define the morphology of melt inclusions in stressed icy aggregates, allowing the intern to draw comparisons across stress and strain regimes that will help create a comprehensive understanding of how meltwater evolves during deformation. The intern will then compare these results to modeled orientations from a microstructural simulation software, and produce recommendations for future updates to this software.

Prerequisites: No laboratory experience is necessary, but a willingness to get your hands cold and a little bit dirty is helpful.

Mentors: Cassandra Seltzer, cls2207@columbia.edu; Christine McCarthy, mccarthy@ldeo.columbia.edu

Quantifying the Value of Climate Information for Adaptation

Background: The proposed project will develop and analyze mathematical models to structure our understanding of climate risk. “Climate risk” refers to a probabilistic understanding of the potential impacts of climate variability and climate change, accounting for uncertainties, and encapsulates our scientific understanding in the form most relevant for adaptation.

Practices and conventions differ across the multiple contexts and fields in which climate risk is assessed, limiting understanding and confidence in the results. This project will be part of a larger effort aiming to build a synthetic and general understanding, using the so-called value of information (VOI) approach from economics, in combination with climate science models and data sets.

In the VOI framework, different adaptation decisions are represented mathematically via thresholds on the input climate data, e.g., if the probability of temperature exceeding some threshold is greater than some value, take some action; otherwise don’t. Combined with a function that determines the cost of a wrong decision, the relative value of different sets of climate data, such as from different climate models, can be determined. This framework allows us to compare different types of adaptation decisions, depending on different metrics of the climate information, and understand how they place different needs on the climate science. Examples may be taken from highly idealized, low-dimensional climate models, or more realistic examples, perhaps including models of hurricane or heat wave risk.

Work Required: Analysis of climate data sets and incorporation of them into the value of information framework, i.e., data analysis and mathematical modeling on the computer.

Pre-requisites: Calculus, differential equations, statistics, and programming (preferably in Python). Knowledge of climate science and/or economics is desirable but not strictly necessary. This is a project with a theoretical as well as an applied component, so some interest in mathematics and/or mathematics based sciences will be helpful.

Mentor: Adam Sobel, ahs129@columbia.edu

What Can Oxygen Isotopes in Aquatic Plants Tell Us About Arctic Climate?

Background: Plant tissues are primarily composed of carbon from atmospheric carbon dioxide (CO_2) and hydrogen and oxygen from water (H_2O) taken in at the roots or by direct absorption in nonvascular plants. The oxygen isotope composition (δ18O) of environmental water is controlled by regional climate conditions, including temperature, moisture source region, and/or sea-ice extent depending on location. This isotopic signature is imparted into compounds produced by plants as they grow, meaning that sedimentary records that preserve plant biomarkers can be used to reconstruct past regional climate change. In Northern Greenland, where the impacts of modern global warming are particularly extreme due to Arctic amplification, these tools are critical for understanding past local climate dynamics and better predicting the future.
Recent studies have shown that aquatic mosses can be used to measure interseasonal variations in oxygen isotope composition of lake water in Greenland, which is controlled by precipitation δ18O and evaporation. However, this novel proxy has not been applied in a paleo setting and may offer new, high resolution insight into past climate change.
As an intern, you will work to produce a preliminary 6,000-year record of summer aquatic moss δ18O for Lake Latesommersø in Inutoqqat Nunaat, Northeast Greenland. Sediment records from Latesommersø and neighboring Nedre Midsommersø have already been used to construct alkenone-based temperature records for the region, as well as records of ice cover inferred from diatom diversity, and plant-wax hydrogen isotopes (δ2H). Thus, this project offers a prime opportunity for assessing the viability of aquatic moss as an indicator of source δ18O in sedimentary archives, with opportunities to contextualize the dataset against a number of biomarker records from the same lake system.

Analysis Required: This project will involve analyzing the isotopic composition of summer mosses across a sediment core from Northeast Greenland. Lab work will involve isolating mosses from sediment, separating out summer growth segments, and measuring δ18O of bulk tissue using a thermal conversion/elemental analyzer-isotope ratio mass spectrometer (TC/EA-IRMS). Lab work, including training, will likely average ~25 hours a week.

Prerequisites: Two semesters of General Chemistry. Lab courses in chemistry or biology, or equivalent experience working in a wet lab setting. Organic chemistry and biology are recommended but not required.

Mentor: Redmond Stein, redstein@ldeo.columbia.edu, 973-558-4141
William D’Andrea, dandrea@ldeo.columbia.edu,

Do Catastrophic Explosive Volcanic Eruptions Affect the Long Term Evolution of the Climate?

Background: The catastrophic eruption of the volcano Mt. Tambora (Indonesia) in the year 1815 is the most powerful recorded in human history. The eruption is famous for having caused global cooling that resulted in failed crops and famine for three consecutive summers in the Northern Hemisphere, which includes 'the year without a summer' in 1816 that brought snow and frost in June to New England. The direct and indirect death toll exceeded 100,000 human lives. There is no doubt that the impact of such an eruption on human civilization would be much worse than 200 years ago. But what is the likelihood that such eruptions will re-occur? We know that such large eruptions often happen on the geological time scale. There are also indications that these eruptions do not occur randomly but may synchronize with the Earth's climate evolution over time. The latter observation has sparked much discussion about whether climate change leads to more explosive volcanism, and whether 'volcanic winters' can offset global warming. To better understand such connections, we investigate links between large volcanic eruptions and the global climate over the past few million years. Because on land volcanic records older than a few 10,000 years are usually destroyed by erosion or buried under younger geological material, we establish such time series from drill cores of the marine sediments that were recovered from the ocean basins, and that contain the full geological record of catastrophic explosive volcanism as well as a record of the climate evolution. We will compile the volcanic and climate record of ODP Site 887 in the North Pacific Ocean outboard of the Alaskan volcanic arc. Does the record of this drill site confirm or refute a connection between explosive volcanism and climate? Does catastrophic explosive volcanism contribute to periodic global cooling and/or warming?

Analysis Required: This project uses existing data from the International Ocean Discovery Program (IODP). The student will identify ash bed layers from ODP Holes 887 (North Pacific) from high quality core images and other existing ODP expedition data, compile them into a database, and calculate their ages. This will be followed by modeling minimum eruption sizes using existing (simple) algorithms, and a range of potential sources and ash distribution patterns. Ideally, there will be an assessment about fluctuations of volcanic eruptions through time. Work will require ~25 to 30 hrs./wk. (This is flexible).

Prerequisites: The student should be able to run Excel and PowerPoint on their laptop. The project is a great learning opportunity about the IODP which manages the largest international archive of geological data and samples from the ocean floor.

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What Factors Drive Forest Soil Health and Soil- Water Dynamics?

Background: Soil health and soil-water dynamics can greatly influence forest growth and biodiversity, both of which are vital to preserve in an era of increasingly extreme weather events. In 2024, a one-hectare experimental research site was established at the Lamont Sanctuary Forest on campus to support student involvement in research and education. Initial baseline measurements of soil health were conducted that year, and changes in soil conditions will be tracked through this proposed project to identify key environmental factors influencing forest soil health. To expand the scope of monitoring, we also propose incorporating a novel high-throughput method for tracking soil water dynamics. This addition will help pinpoint potential constraints affecting forest and soil health, guiding the design of future conservation strategies that enhance multiple ecosystem services. The project will pair in-situ measurements of soil health and water dynamics with satellite and drone imagery, along with GIS-based extraction of environmental data layers and modeling techniques, to enable an advanced characterization of spatiotemporal soil dynamics at the site level. This proposed work will serve as one of the initial steps toward fully establishing a long-term experimental site on campus, which will contribute to continued student engagement and advancing research efforts in forest and soil conservation.

Analysis Required: This project will involve grid-based soil sampling from the Lamont campus forest experimental site, followed by laboratory soil processing and testing of a range of soil health indicators. The student will also gain experience operating a unique HyProp-based lab system to obtain soil moisture release curves from field samples. Additionally, the student will have opportunities to develop skills in processing sensor datasets, conducting model based spatial analysis, and collaborating with other Lamont members working on relevant projects. Field and lab work will average 30 hours per week, with the remaining time focused on data and image analysis, literature review, report writing, etc.

Prerequisites: A strong interest in addressing environmental challenges through field and lab-based research is required. General chemistry and laboratory courses or prior experience handling soil samples would be a plus.

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