What is the Origin of Two Deep Circular Lakes in the Russian Heartland?

Background: The Russian heartland between Moscow and Nizhne Novgorod contains many deep, circular lakes. Two are widely regarded as possible impact craters: Lakes Smerdyachee and Svetloyar. We have collected samples around these lakes to better constrain their origin. Smerdyachee has a rim-to-rim diameter of 409±6 meters. Modeling predicts impactor fragments of iron meteorite on its downrange end. We have collected samples of magnetic concentrates around Smerdyachee and samples of a possible distal ejecta layer from a nearby riverbank. At Svetloyar, the lake is elliptical, with a prominent hill on the downrange end. We have samples from the downrange end that we know contain unusually high concentrations of melted Sn. These could be impactor fragments or simply an unusual layer in the soil. Because Lake Svetloyar is larger than Smerdyachee, samples from the downrange end have a better chance of containing impact glass or shocked minerals.

Analyses Required: The student will process magnetic samples from both Svetloyar and Smerdyachee and will search for impactor and impact melt fragments using light microscopes and a scanning electron microscope. Large fragments will be made into thin sections and examined petrographically. We will also sieve samples for ^{14}C dating above, in and below the distal ejecta layer. (The lakes may date to just after the last glacial maximum.) The student will also process samples from Svetloyar for heavy minerals. The goal is to look for possible shocked minerals with high density such as coesite, stishovite and zircon. The student will also process and examine high-resolution satellite images of the two lakes in preparation for fieldwork in mid-August. The goal will be to use multispectral images to search for iron or carbonate rich areas-possible small subsidiary craters or areas of deep excavation of the carbonate basement.

Prerequisites: Interest and enthusiasm. Ability to speak a foreign language fluently and petrographic skills are desirable but not essential. Participation in fieldwork in mid August is possible but not guaranteed.

Mentors: Dallas Abbott (dallashabbott@gmail.com) and Gary Mesko (mesko@ldeo.columbia.edu)

Fig. 1. Panorama of Lake Smerdyachee (after Badjukov, 2003; LPSC Abstr. 1566)

Why are dinoflagellates taking over the Arabian Sea?
Testing hypotheses using incubation experiments

Background: Over the last two decades, the northern Arabian Sea has undergone a radical ecosystem shift. Mixotrophic dinoflagellates (i.e., *Noctiluca scintillans* – as shown in Figure 1 – and to a lesser extent, *Cochlodinium polykrikoides*) have replaced diatoms at the base of the marine food web. This shift has disrupted the delicate balance of the ecosystem, causing a decline in biodiversity and damage to local fisheries. It is thought that the expansion of the Arabian Sea "dead zone" (a zone of low oxygen water) has prompted the recent dinoflagellate blooms. In addition, mineral dust inputs to the northern Arabian Sea – particularly from the Arabian Peninsula – may be contributing to the development of the blooms.

The objective of this project is to determine whether the dinoflagellates in the Arabian Sea ecosystem are uniquely adapted to the recent low oxygen/high dust conditions. Our laboratory has developed a novel incubation system to control dissolved gases in culture. In order to examine the effects of low oxygen and dust inputs on dinoflagellate growth, laboratory incubation experiments will be conducted using this system. Cultures of *N. scintillans* and *C. polykrikoides* will be examined under a range of conditions. The duration for each experiment will be approximately 3-4 weeks.

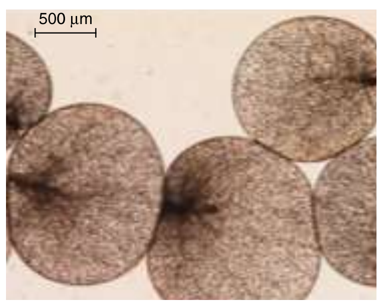

Figure 1: *N. scintillans*, the primary mixotrophic dinoflagellate taking over the Arabian Sea (Gomes *et al*., 2014)

Analyses Required: This project will require participation in controlled incubation experiments in the laboratory. Both *N. scintillans* and *C. polykrikoides* cultures will be examined under a range of oxygen and dust conditions. Over the course of each incubation experiment, the following measurements will be obtained and analyzed: pH, dissolved oxygen, chlorophyll *a*, cell counts, variable fluorescence, nutrients, and trace metals.

Prerequisites: There are no official course prerequisites for this project, but a basic knowledge of ocean science and a desire to undertake laboratory-based experiments are required.

Research Mentors: Alexandra Bausch (primary mentor, post-orals graduate student with permission of advisor, Joaquim Goes), abausch@ldeo.columbia.edu, (845) 365-8781; Joaquim Goes (secondary mentor), jig@ldeo.columbia.edu, (845) 365-8467

Does understanding Manhattan microweather help with Manhattan building performance predictions?

Background: Our group has ongoing projects that use weather observations and weather forecasts based at Central Park to predict building energy demand and other like predictions for several large buildings in Manhattan. Temperature and relative humidity sensors are available at the large buildings. This data would be available to relate to observed building performance data to compare predictions made by local weather data against predictions using the Central park NOAA weather station.

Analysis Required: This project will require gathering the data from existing databases and running the prediction models on the data and comparing the results to our current predictions. Access to weather forecasts via the National Digital Forecast Database in order to interpolate a forecast for the building location and the W underground Weather API is also required. We wish also to geospatially map these observations.

Prerequisites: Some experience with computer programing and databases, scientific analysis using spreadsheets and geospatial plotting. Some experience with NOAA weather observation and NOAA forecast product data including the National Digital Forecast Database and its access with REST web service, SOAP or IDV would be a plus but not required. The project also uses the Wunderground Weather API, see http://www.wunderground.com/weather/api/

Thesis Mentors: Albert Boulanger: aboulanger@ldeo.columbia.edu, 917 684-8974 Roger Anderson anderson@ldeo.columbia.edu, 713 398-7430,

What do Trans-Fats have to do with Climate Change? Studying Earth's best natural thermometer

Background: How do we know what Earth's temperatures were before there were thermometer measurements? Climate scientists have devised a few ingenious ways to read ancient temperatures from ocean sediments, ice cores, and tree rings… but the *best* paleothermometer is a fat molecule produced by single-celled algae. Alkenones are very unusual fats made only by certain algae, and in the structure of these lipids is recorded the temperature of the water in which the algae grew. We can look at these fat molecules in our lab - preserved for tens, thousands, or millions of years in mud at the bottom of the ocean - and figure out the temperature of the water at the time the algae lived. We are trying to better understand *how* and *why* these fats record water temperature and if there are other factors that influence them besides temperature. To do this, we are growing a number of different species of algae at different temperatures (and other growth conditions) and then examining the fats that they produce. This project will directly lead to the advancement of the world's best paleothermometer.

Watch a short video about alkenones by one of the project mentors:
http://icestories.exploratorium.edu/dispatches/alkenones-natural-thermometers/

Analysis Required: This project will involve culturing live algae and extracting and analyzing the fats they produce. The student researcher will get to work in both a biological lab and an organic geochemistry lab and will learn many of the skills used in the growing biofuels industry.

Prerequisites: None necessary.

Mentors: Billy D'Andrea: dandrea@ldeo.columbia.edu , (845) 365-8654
Andy Juhl: andyjuhl@ldeo.columbia.edu , (845) 365-8837

How did the Pacific Ocean transport heat in the past?

Background: Deep-water ocean circulation is fundamental to the earth's climate because it distributes heat, salt, carbon and nutrients globally. Investigating how ocean circulation has changed in the past is vital to understanding heat and carbon storage on long time scales. Today, surface water in the North Atlantic and Southern Ocean sinks into the ocean's depths to become deep-water. However, there's evidence that deep-water formation also took place in the North Pacific around three million years ago. During this time, global temperatures were 2-3 °C warmer than today and carbon dioxide levels were similar to current levels, therefore this period serves as a possible model for future climate change. Two major climate transitions happened since: Northern Hemisphere Glaciation (2.73 million years ago) and the establishment of modern tropical Pacific conditions (2.0 million years ago). How did deep-water circulation in the North Pacific change during these times and alter heat and carbon storage of the deep ocean? This project uses a marine sediment core from the California Margin collected by the Ocean Drilling Program (ODP 1014). By using the chemistry of fossil shells found in marine sediment, we will estimate the deep-water temperature over these transitions. Combining these temperature estimates with previously published carbon isotope data, we will be able to evaluate changes in North Pacific deep-water circulation and it's influence on global climate.

Analyses Required: This project will require some microscope work identifying and sorting fossil shells. Laboratory work will include chemically cleaning the shells and analyzing samples on Inductively Coupled Plasma-Mass Spectrometer (ICP-MS). Lab work will require 20 hours/week.

Prerequisites: None. Knowledge of chemistry background is a plus.

Mentor: Heather Ford, hford@ldeo.columbia.edu, 845.365.8406

Is pink the new white?
A comparison of the geochemical signatures of *Globigerinoides ruber* chromotypes

Background: *Globigerinoides ruber* is one of the most commonly used planktonic foraminifera in paleoclimatic reconstructions. The calcium carbonate shells of these unicellular organisms are abundant in the marine fossil record and have proven invaluable in reconstructing past sea surface temperature and salinity, and in providing radiocarbon dates for marine sediment samples.

The majority of published research has focused on the white variant of *G. ruber* but a pink form is also abundant in the Atlantic Ocean (and historically in the Pacific and Indian Oceans). The reason for the difference in pigmentation is not well understood, and geochemical offsets in the shells of these two chromotypes have been demonstrated in localized basins but remain largely unexplored. This project will teach the student the geochemical tools to examine pink and white *G. ruber* and help clarify the environmental conditions that favor each chromotype. If the results indicate that geochemical differences between chromotypes are due to different depth or seasonal niches, this research will open the way for future studies of *G. ruber* aimed at reconstructing changes in upper water column structure and/or seasonality in paleorecords. This research project will complement existing and ongoing research into differences in radiocarbon dates between pink and white *G. ruber* variants.

Analysis Required: The student will learn to identify and pick foraminifera from marine sediment core samples and analyze these foraminifera for stable oxygen and carbon isotopes on a mass spectrometer. Trace element analyses are also a possibility if the student is interested. These techniques are among the most fundamental tools of paleoclimatology/paleoceanography and provide a strong foundation for future work in the field.

Prerequisites: None, although some knowledge of Earth's climate system would be helpful.

Project Mentors: Allison Jacobel (jacobel@ldeo.columbia.edu), and Jerry McManus (jmcmanus@ldeo.columbia.edu)

How dry and how long were the most extreme arid periods in the Middle East? Reconstructing water budget and water sources using Dead Sea sediments

Background: The Middle East is a region where water is a scarce resource, and climate models predict a drier future in a warmer world. In the Dead Sea (Israel, Jordan, Palestine) salt (mainly halite) has precipitated during the driest periods of interglacials. The warmest period of the last interglacial was characterized by an unstable climate, with sharp changes between wet and very dry periods that were much drier than today. This project aims to characterize these dry and wet cycles and identify the sources of water in the region. The Dead Sea watershed stretches between the Saharan-Arabian desert belt and the Mediterranean climate zones, and different climate indicators show the interplay of these systems through time. Questions addressed are: *How dry was it? For how long? How abrupt were the transitions between the wetter and drier climate? When (summer or winter) and where (the tropics by increasing monsoon activity or from the Mediterranean) did the moisture come from?* ***These questions are crucial for future planning and water management in a future warmer Middle East.***

During 2010–2011 the Dead Sea Deep Drilling Project drilled more than 460 meters in the deepest basin of the Dead Sea and recovered sediment covering the last ~200,000 years, including the last 3 interglacials and the last 2 glacials. The cores reveal long sections containing layers of salt (halite), which represents periods of extreme aridity and indicates dropping lake levels. The types of sediment and their chemistry provide important information on lake level changes and volume, nevertheless, we need more constraints on the ages as well as on contributions from the different water sources. We will use dating approaches and stable isotopes to better constrain ages of events during the last interglacial, and Sr and Nd isotopes to identify the water sources.

Methods: The project involves processing of solid samples (dissolving, crushing and rinsing) in the Lamont ultra-clean chemistry lab (4 weeks), and measurements using ICP-MS (2.5 weeks). The remainder of the time will be spent on processing the data, combining it with other existing data and paleoclimate interpretation. This project may be expanded to a senior thesis project, including interpretation of other elements measured in the salt, comparison of different salt precipitation intervals and study of fluid inclusions.

Mentors: Yael Kiro ykiro@ldeo.columbia.edu, (845) 365-8916, Steve Goldstein steveg@ldeo.columbia.edu, (845) 365-8787

The Dead Sea basin is located between two major climate systems: the Saharan–Arabian and the Mediterranean. The figure shows the location of the ICDP drilling site at the center of the modern lake, at a water depth of 300m.

Halite from the Dead Sea core, (left) showing seasonal layering; (right) a polished thick-section showing alternations between large crystals that grow on the lake floor, and fine crystals that are formed at the water surface.

How Old is the Dust? Can we use K-Ar to show where dust comes from in the Southern Hemisphere?

Background:

Where mineral dust or aerosols come from and how the sources change over time, especially when climates shift during Ice Ages, remains poorly understood. Such knowledge can help us resolve how air moves around Earth in different climate states, the overall roles of dust in past climate including on biogeochemical cycles in the Southern Ocean where productivity may be influenced by the arrival of dust-bound iron, and changes in dust fluxes. The sedimentary or geologic record can provide important information on possible sources of atmospheric dust in the past. This is because the composition of dust reflects its provenance (=location of origin) and is a primary means to trace past atmospheric circulation patterns. Traditionally, strontium (Sr) and neodymium (Nd) isotopes have been employed to distinguish different potential source areas of dust. Despite much success with these isotope systems, it is difficult to distinguish unambiguously some areas that could provide possible sources of dust to the atmosphere during Ice Ages. This is especially so in the Southern Hemisphere, where both New Zealand and Patagonia may have been important dust sources to the Southern Ocean and Antarctica, because these two areas contained glaciers that erode and create new materials for winds and rivers to pick up. Therefore, there is a pressing need for additional tools to be developed that allow discrimination among these different areas, especially when prior methods are limited. We want to develop the potassium-argon (K-Ar) method as a dust provenance tracer. Given the range of ages of bedrock from different regions around the Southern Hemisphere, we expect sources of dust to provide distinct K-Ar signatures. The intern will carry out K-Ar analyses (geochronology) on sediments already collected in New Zealand and Patagonia.

Analysis Required: The intern will work through the entire process of sample preparation, analysis, and interpretation. They will gain experience with common laboratory procedures used for sediment processing, and with K-Ar geochronology, including quadrupole and noble gas mass spectrometry. The PIs will help guide interpretation of the data and include the intern in discussions about broader impacts of the research.

Prerequisites: None, although introductory geology and chemistry is a big plus.

Mentors:
Bess Koffman, bkoffman@ldeo.columbia.edu, (845) 365-8793
Cristina Recasens, recasens@ldeo.columbia.edu, (845) 365-8793
Michael Kaplan, mkaplan@ldeo.columbia.edu, (845) 365-8646
Sidney Hemming, sidney@ldeo.columbia.edu, (845) 365-8417

How reliable is the modeling of climate forcing from volcanic eruptions?

Background: Despite their short lifetime compared with the long-lived greenhouse gases (e.g. CO_2, N_20, CH_4), volcanic aerosols in the stratosphere have been the largest radiative forcing agents on the climate for the last millennium until the dramatic increases in greenhouse gases during the 20th century. The eruption of Mt. Pinatubo in 1991 is estimated to have had a global peak radiative forcing of ~-7W/m^2, more than double the anthropogenic forcing from all greenhouse gases.
The current implementation of volcanoes in global climate models is relatively simple. The "eruptions" are actually specified sulfate layers in the stratosphere from *observations* of the evolution of sulfate after the eruption of Mt. Pinatubo. Other events are a scaled version of the Mt. Pinatubo eruption. These simulations produce a climate response that is consistent with these observations. However, they lack the ability to predict the impact of a volcanic eruption before these observations have occurred. Moreover, the coordinated experiments conducted for the last IPCC report had many disparities between the predicted model response to large eruptions and climate observations from that period. Many of the largest eruptions – e.g., Samlas (A.D.1258, ~10x Pinatubo) and Kuwae (A.D. 1453) – have a disparity between models and observations of their climatic effects. We do not understand the cause of this disparity.
Here we will investigate whether the implementation of volcanic eruptions in the climate model is responsible for this mismatch. This project will also work toward building a model capable of *predicting* the impact of volcanoes from the original emissions. We will use NASA Goddard Institute for Space Studies General Circulation Model paired with the MATRIX aerosol microphysics modules. These tools will serve as a laboratory for us to investigate the impact of volcanic emissions on climate.

Analysis Required: This project will require analysis of general circulation model simulations from NASA GISS with output in netCDF. The student will compare simulated climate responses to satellite observations from the Mt. Pinatubo eruption. The student will also contrast the difference between the old implementation of large volcanic "eruptions" and this new implementation. This project could contribute to a short paper if the student is motivated.

Prerequisites: Experience with a programming language is required e.g. Python, FORTRAN, IDL, R, or MATLAB. The student will be at NASA GISS in the city. The student needs to be detail-oriented and ready to learn. Atmospheric science and chemistry courses would be useful, but are not required.

Thesis Mentors: Allegra LeGrande, legrande@ldeo.columbia.edu, Kostas Tsigaridis, Kostas.Tsigaridis@columbia.edu

What controls the stability of lava domes?

Background: Lava domes are formed when the erupting lava is too viscous to flow freely, yet there is not enough gas to create an explosion. In recent years, lava domes collapses and pyroclastic flow generation caused great damages at Unzen, Japan (1991), Merapi, Indonesia (1994), Soufriere Hills Volcano, Montserrat (1997), which caused over 100 deaths, and currently Sinabung, Indonesia. In order to provide prediction tools for dome hazards, it is important to understand what controls the stability of lava domes.

The mechanical stability of a dome depends on many factors, both internal, including the distribution of vesicularity, temperature, and crystallinity, and external, such as the underlying topography and slope. In addition, domes are inherently three-dimensional and often asymmetric. However, most models of lava dome evolution assume either relatively simple fluids, a flat bed, and/or a two-dimensional dome.

Intern project: We will address questions regarding dome evolution and stability using analogue fluid experiments in the lab. The student will prepare mixtures of syrup, bubbles and crystals at different rations, and characterize their viscosity using a viscometer. Next, the student will create domes by “erupting” the mixtures through conduits onto varying topographic models (caldera, hill slope…) The student will document the evolution of the domes using an array of cameras and will create 3D reconstructions of the dome surface to capture pre- and post-collapse structures. We will compare modeled domes with natural cases.

Prerequisites: Experience using Matlab and laboratory experience are a plus.

Project mentor: Einat Lev (einatlev@ldeo.columbia.edu)

Evolution of the dome at Sinabung in dome-flow between 16 and 20 January 2014. Images: Fabrice Digonnet

Lava dome within Mount St. Helens’ crater, September 2006. Image: Willie Scott, USGS

Soufriere Hills volcano lava dome, Montserrat 2010. Image: PhotoVolcanica.com

Where does the Carbon go? Assessing Small Urban River Weathering in New York City

Background:

In this project, the intern will conduct pioneering carbon studies in the Bronx River in New York City. Carbon sources, sinks and its role in healthy ecological processes have been ignored in urban centers until recently. This project includes the exploration of organic and inorganic forms of carbon in small urban rivers (SURs), which still make up a major void in the understanding of biogeochemical cycles in urban systems. In addition to closing the carbon balance, carbon can be directly linked to ecosystems. The estimate of carbon remains highly variable and is dependent on rain events and the geology of the region. Carbon transport from these small rivers may increase organic carbon deposition; promote shoreline food webs and heterotrophy. Furthermore, significant anthropogenic influences such as combined sewage overflows (CSOs) have radically changed the cycling, transport and hydrology of carbon in urban rivers.

Analysis Required:

This project will require travel to the Bronx River, the Botanical Gardens, and the Bronx Zoo to collect water samples and take water quality measurements under supervision of research staff. The parameters include Dissolved Organic and Inorganic Carbon (DOC and DIC), Particulate Organic Carbon (POC), Total Suspended Solids (TSS), pCO_2, temperature, salinity, pH, dissolved oxygen and turbidity. Effort will include analyzing the water samples and working on data analysis on other parameters indicated above.

Prerequisites: None, although previous wet lab and field experience is a plus.

Mentors: Wade McGillis: mcgillis@ldeo.columbia.edu, 845-365-8562; Diana Hsueh: dhsueh@ldeo.columbia.edu, 310-367-7100

Whither ^{231}Pa and ^{230}Th in the Gulf of Aqaba, Red Sea?

Background: The isotopes ^{230}Th and ^{231}Pa are produced in seawater at constant rates from the decay of dissolved uranium isotopes. That makes them extremely valuable for assessing the rates of a number of oceanographic processes, from biological productivity, to sediment accumulation, to abyssal ocean circulation. Both isotopes are rapidly scavenged from the water column onto settling particles and deposited into the underlying sediments, resulting in large ^{230}Th and ^{231}Pa deficits in the water column, compared to the more soluble uranium, and large excesses in the underlying sediments. During particle sinking however, the scavenging by adsorption onto particles is partially balanced by desorption from the particles, resulting in a loss of a fraction of these isotopes back into the dissolved phase, which thus requires consideration when interpreting downcore records of marine sediments. Yet the dynamics of this reversible exchange are poorly understood, and direct observations have thus far been limited.

This project will focus on measurements of ^{230}Th and ^{231}Pa in a high-resolution time series of marine particles collected in sediment traps from the Gulf of Aqaba. This dataset will serve as the first ever measurement of its kind in the Red Sea, and provide important constraints on our understanding of reversible-exchange scavenging in this environment, including the possible difference between seasonal and episodic effects such as abrupt storm events on the scavenging processes. The results will allow future investigation of nearby downcore records and the reconstruction of productivity and ocean circulation patterns in the Gulf of Aqaba, which will also serve as a microcosm for similar processes in the global ocean.

Lab work and data analysis: The student will travel to Eilat, Israel, where she or he will be hosted at the Interuniversity Institute (IUI) for Marine Sciences and take part in a cruise to recover and re-deploy sediment traps in the Gulf of Aqaba. Preliminary sample treatment will take place at the IUI and will continue at LDEO. Processing will include digestion of the samples, purification of the Th and Pa fractions through column chemistry, and analyses using a mass-spectrometer. The student will spend approximately 2-5 weeks at the IUI, and upon return to LDEO will be expected to spend approximately 30-35 hours / week.

Pre-requisites: First year college level chemistry and preferably some familiarity with ocean science.

Mentors:
Prof. Jerry McManus, jmcmanus@ldeo.columbia.edu, Tel: +845-365-8722
Dr. Adi Torfstein, adi.torf@mail.huji.ac.il, Tel: +972-8-6360195

How Deep are the Roots of the North American Continent?

Background: The northeastern part of the North American continent was assembled during three great continental collisions, spanning a period of over three billion years, as is evidenced by the geologic ages of surface rocks in the several terranes and the geological structures within them. Continents, however, are more than rocks exposed on the earth's surface; their roots, which extend to several hundred kilometers depth, are the regions where plate-tectonic forces are in play. Although deeply buried, continental roots can be studied using seismic imaging techniques, similar to medical imaging, which use seismic (earthquake) waves to probe structure. In 2012-13, we deployed a line of seismometers across Maine and Quebec, which is now collecting earthquake data. These new data can be used to address three important questions related to continental evolution: 1) whether the major terrane boundaries have a deep seismically-imageable expression that cuts across the pattern of preexisting lithosphere; 2) whether the lithosphere-asthenosphere boundary deepens towards the center of the continent and 3) whether the pattern of foliation (rock fabric) in continental roots is primarily an asthenospheric signal associated with present-day mantle flow, as contrasted to a relic of ancient events. A preliminary look indicates that the data are sufficient to address these questions and has already yielded surprises.

Analysis Required: The intern will be involved in analyzing and interpreting this novel data set and may also take part (schedule permitting) in field trips to download data and service the seismometer sites.

Prerequisites: The intern needs to be willing to learn a little seismology and to spend a long time staring at wiggly lines. Some prior exposure to the physics of vibrations and waves and to data analysis would be helpful.

Mentor: Bill Menke (menke@ldeo.columbia.edu, http://www.ldeo.columbia.edu/users/menke/, 845-304-5381)

Can New Zealand Peatlands Reveal the Drivers of Late Glacial Rise in Atmospheric CO_2?

Background: The strength and latitudinal position of the Southern Hemisphere westerly winds play a fundamental role in the global carbon cycle by regulating Southern Ocean CO_2 flux. Modeling studies indicate that when the winds are centered over the Antarctic Circumpolar Current, upwelling of carbon-rich deep water enhances ventilation and outgassing of CO_2 to the atmosphere. In contrast, when the main axis of the winds shifts to the north, CO_2 uptake processes dominate and more atmospheric CO_2 is entrained in descending intermediate waters. The westerly winds' influence on the carbon cycle is key to current hypotheses on the mechanisms for glacial-interglacial change. In particular, the Late Glacial transition into the Holocene is an important time in Earth's climate history, and though it is well studied, questions about the deglacial rise in CO_2 and its temporal relationship with warming in the Northern and Southern hemispheres remain. Questions also remain regarding discrepancies between the timing and magnitude of temperature changes in marine and terrestrial temperature records.

In order to constrain the westerly wind influence on the global carbon cycle, and provide a record of climate variability that will place the magnitude of recent hydrologic change occurring in the Southern Hemisphere in a longer perspective, we will use high-resolution paleoclimate records obtained from peatlands and lakes on New Zealand's South Island and Auckland Islands to reconstruct past changes in climate and vegetation related to the Southern Hemisphere westerly winds. Cores were collected on recent research expeditions on the University of Otago's research vessel *Polaris II* to the Auckland Islands. The primary goal is to reconstruct changes in the strength and latitudinal position of the westerly winds using changes in abundances and hydrogen isotope ratios of individual biomarkers, which are sensitive recorders of vegetational and hydrological change, respectively.

Analysis: The student will use the abundances and hydrogen isotope ratios of sedimentary leaf waxes to reconstruct the moisture balance and hydrogen isotopes of precipitation respectively from peatlands New Zealand's South Island. The student will be extracting, purifying, quantifying, and measuring stable hydrogen and carbon isotope ratios of leaf wax *n*-alkanes.

Prerequisites: None, although steady hands and attention to detail are a plus.

Mentors: Jonathan Nichols jnichols@ldeo.columbia.edu x8428 and Dorothy Peteet peteet@ldeo.columbia.edu x8420

Where’s the P in plankton? An investigation of marine microbial strategies for phosphorus use

Background: Phosphorus is one of the key elements for life, but it is in scarce supply in much of the ocean—how do microbes manage this limited resource? In every drop of ocean water there are more than 100,000 microbes, even in areas where phosphorus and other nutrients are scare, such as the large open ocean gyres in the North Atlantic and North Pacific. In these low nutrient environments, small unicellular prokaryotic microbes, particularly cyanobacterial phytoplankton and non-photosynthetic heterotrophic bacteria, dominate the microbial community. Each type of microbe plays a distinct functional role in the ecosystem, and different groups compete for limited resources. We are investigating the unique strategies employed by different types of microbes for the acquisition and utilization of the scarce nutrient phosphorus. Microbes need phosphorus to build DNA and RNA, and many other cellular materials including lipid membranes and energy-trafficking molecules such as ATP—when phosphorus is in low supply microbes may use a variety of physiological adaptations to shift the allocation of phosphorus from one cellular pool to another or to decrease their total phosphorus demand altogether. We will be developing and refining methods for measuring the microbial uptake of phosphorus and the allocation of phosphorus into different cellular biochemicals. We’ll be employing these methods to compare the phosphorus strategies employed by cyanobacterial phytoplankton and heterotrophic bacteria, both in cultures in the lab and from field samples collected in the low-nutrient Sargasso Sea in the North Atlantic Ocean.

Onboard the R/V Atlantic Explorer as it heads out of port in Bermuda for a research expedition in the Sargasso Sea

Analysis Required: This project will require field sampling in the Sargasso Sea, near Bermuda, aboard the research vessel the Atlantic Explorer. This trip will last 8-9 days with 6 days spent at sea. The remainder of the summer will be spent growing cultures of microbes in the lab and measuring phosphorus in cellular biochemicals using a mix of chemical and biological tools. Lab work will require 35 hrs. /wk.

Prerequisites: None, although knowledge of chemistry, biology or lab experience are a plus.

Project Mentors: Kim Popendorf, kimdorf@ldeo.columbia.edu, 845-365-8774

How will future climate variability and change impact water and resources, and ecosystems across western North America?

Research Project Description: Western North America, from the monsoon regions of Mexico, to the deserts of the southwest and the semi-arid Plains, is a diverse area influenced by several climate phenomena including the North American monsoon, the Pacific storm track, the Pacific subtropical High and the Great Plains Low Level Jet. It is also a region of great year-to-year and decade-to-decade climate variability oscillating between droughts and pluvials. Furthermore climate is changing across the West and these changes, including further aridification of the southwest and warming everywhere will intensify in coming decades. These changes pose challenges for water resources, management of land (e.g. rangelands) and ecosystems. The goal of the project will be to better understand links between climate variability and change and a chosen management issue. The particular issue will be chosen in consultation with the student but could include a water resource matter (e.g. climate impacts on regional river flows), links between climate and migration patterns, changes in extreme weather events, climate change impacts on endangered species, climate-driven changes in ecological zones and so on.

Analysis required: The work will be done via online research collecting data on the chosen topic and analyzing this in combination with our in-house collection of historical climate data and archives of model simulations of the past and projections of future climate.

Prerequisites: The student should know some basic statistical techniques and also have familiarity with climatology and meteorology. Some knowledge of ecology might also be useful but is not essential.

Mentors: The student will be advised by a team of climate researchers at Lamont all of whom are involved in the western climate and land management project. Richard Seager (seager@ldeo.columbia.edu) will be the main mentor and others might include, depending on the exact project: Jason Smerdon (jsmerdon@ldeo.columbia.edu) , Ben Cook (bc9z@ldeo.columbia.edu), Park Williams (Williams@ldeo.columbia.edu), Mingfang Ting (ting@ldeo.columbia.edu), Yochanan Kushnir(kushnir@ldeo.columbia.edu).

How old are African savannas?

Background:
The modern savanna ecosystems of East Africa host a diverse and iconic suite of fauna that includes lions, giraffes, elephants, wildebeest, and zebras. When did savannas evolve? How did the development of these ecosystems affect the evolution of humans and other mammals? Tackling these questions requires a multi-proxy approach from many different fields within the earth, life, and anthropological sciences. This project will focus on identifying the advent and subsequent expansion of grassland ecosystems in East Africa. We will use molecular biomarkers (i.e. leaf waxes) transported from land to marine sediments off the coast of East Africa to reconstruct vegetation over the past 15 million years, with an emphasis on the last 5 million years, to improve our understanding of the role of vegetation change in human and mammalian evolution.

Ancient leaf waxes will be extracted from marine sediment samples and quantified. Once quantified, the carbon isotope ratios of the leaf waxes will be measured. The carbon isotope ratio will be used to determine the relative proportion of C_3 plants (trees, forbs, and shrubs) to C_4 plants (grasses) that covered the landscape. Carbon isotope data serve as a robust proxy for paleovegetation. The leaf wax isotope data will be integrated into existing data sets from other climate proxies such as fossils, pollen, and soil carbonates.

Analysis Required: The majority of the summer will be spent preparing (cleaning, freeze drying, and extracting) marine sediment samples for analyses by gas chromatograph- mass spectrometry and stable isotope ratio mass spectrometry. Lab work will require 20-40 hrs/wk.

Prerequisites: None, although knowledge of organic chemistry and stable isotope geochemistry is a plus.

Mentors: Kevin Uno: kevinuno@ldeo.columbia.edu, 845-365-8308; Pratigya Polissar: polissar@ldeo.columbia.edu, 845-365-8400; Peter deMenocal: peter@ldeo.columbia.edu, 845-365-8483.