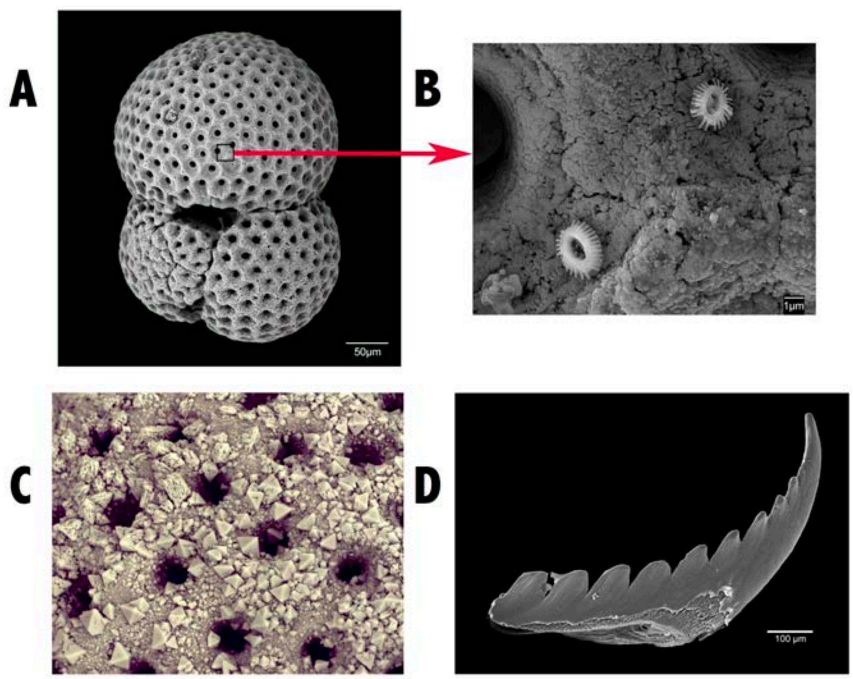
# How Much Climate History Is Encrypted in Hudson River Cores? Can We Break the Code?

**Background:** Hudson River cores are archives of climate history. Sediment layers contain the following potential climatic indicators: 1) tropical to subtropical marine foraminifera-probable hurricane layers, 2) scolecodonts with iodine at the % level-possible paleosalinity indicators, 3) high magnetic susceptibility, shell-rich layers-possible flood events and 4) Sn-Ni coated grains-possible incursions of cosmic dust during times of low solar activity. Until now, all but the layers with high magnetic susceptibility were invisible in images and in geophysical data.

**Analysis Required**: LDEO has a new scanner that can perform detailed XRF measurements of sedimentary composition at sub-centimeter intervals. We will use this scanner to determine how many layer types are routinely observable in detailed geochemical logging. We will use sieved samples from previously studied, high-sedimentation rate cores to ground truth our measurements. We will then extend our geochemical measurements and sieving analyses to newly identified, high-sedimentation rate cores at key locations along the lower Hudson.




Distinctive markers in Hudson R. sediments. A: Tropical foraminifer. B: Coccolith in pores of A. C: Sn-Ni coated foraminifer. D: Scolecodont with I-rich coating.

**Prerequisites**: A strong interest in climate, sediments and geochemistry.

**Mentors**: Dallas Abbott dallashabbott@gmail.com and Karin Block kblock@ccny.cuny.edu

# How Much Melting and Freezing is Occurring Beneath the Ross Ice Shelf in Antarctica?

**Background**: The Ross Ice Shelf, the size of France is the largest ice shelf currently on our planet. In November 2015 the ROSETTA-ICE Team, lead by Lamont scientists and engineers collected the first comprehensive data set capable of looking at both how the ice shelf is changing and what the underlying geology is like. Ice shelves are the floating extensions of the Antarctic Ice Sheet and are where most of its mass loss occurs, by iceberg calving and basal melting. For a steady-state ice shelf, mass loss balances the mass gained through ice inflow across the grounding line and net surface accumulation from local snowfall. Changes in an ice shelf will occur when any of these mass budget terms change. As ice shelves are already floating, changing their mass does not directly influence sea level. However, ice shelves provide a backstress on the surrounding grounded ice, a process known as "buttressing". Reductions in backstress, through reduced lateral stresses or release of a thinning ice shelf from ice rises and other pinning points, may accelerate flow rates of grounded ice to the ocean. The Ross Ice Shelf contributes to buttressing of the Siple Coast ice streams, and major East Antarctic outlet glaciers. Recent results from satellite altimetry have indicted that the Ross Ice Shelf may have shifted modes. In the 1990's the ice shelf was experiencing basal melting in the north and melting in the south. More recent data suggests that the entire ice shelf is now experiencing basal melting.

**Analysis Required**: Radar data over floating ice can be used to map the distribution of melting and freezing when the interfaces are distinct. This project will use the newly acquired ice penetrating radar data over the Ross Ice Shelf to map regions of melting and freezing. The goal will be to test whether there has been a shift in the radar returns. The project steps will include mapping the basal reflectivity in the ROSETTA-ICE data using a MatLab based tool and comparing these results to the distribution of reflectivity observed during the 1970's flights acquired by both the British Antarctic Survey and the US Antarctic Program.

**Prerequisites**: Basic physics and calculus, intense interest in climate change and ice dynamics. Some familiarity with Matlab is desirable but is not required.

**Mentors**: Robin Bell robinb@ldeo.columbia.edu, Indrani Das indrani@ldeo.columbia.edu, and Winnie Chu wchu@ldeo.columbia.edu.

# How Has Sea-Level Changed on the U.S. East Coast, 1955 to present?

**Background:** Sea-level rise is one of the major hazards associated with global warming. Sea-level rise has been recognized as having a major impact on the global economy, and will have major impacts on the sustainability of coastal cities and their population and sustaining future coastal development. Sea-level rise will also have major impacts on the sustainability of coastal resources, including wetlands and fresh water. Sea-level, though, is much more complex than is generally understood, and is a spatially and temporally variable response to present-day mass loss from large ice sheet and glaciers (primarily although not exclusively Greenland and Antarctica), to changes in ocean density and currents, to the ongoing response of the solid Earth to the rapid deglaciation following the last glacial cycle of the ice age, to local ground-water extraction, and even to changes in atmospheric pressure. Using a combinations of models, ground- and space-based satellite observations, I am currently preparing the first comprehensive sea-level change "budget" for sites on the east coast of the U.S., wherein calculated contributions to sea-level rise are compared to observed values for the late 20$^{th}$ and early 21$^{st}$ Centuries. Such a budget will enable us to better understand past sea-level rise and predict future sea-level rise.

**Analysis Required:** The project will require running software to analyze a range of observations and models, and require careful assessment of the capability of these data to predict observed sea-level rise, and to develop methods for graphical representation of the results. No fieldwork is required. The analysis will require 20 hrs/wk.

**Prerequisites:** None, although knowledge of basic physics and/or statistics is a plus.

**Mentors:** James Davis: jdavis@ldeo.columbia.edu, 845-365-8425.

# How fast does magma move during volcanic eruptions?
# An investigation using water in phenocrysts

**Background:** Why do some volcanoes erupt more violently than others? Just like opening a shaken soda bottle too quickly, faster magma movement leads to larger explosions, but determining the exact rate of magma ascent for a given eruption is still a major challenge facing volcanologists. One way to quantify ascent rates is by looking at profiles of water concentrations across large erupted crystals called phenocrysts. The phenocrysts start out below the surface with high concentrations of water, and then during the eruption, that water moves out of the crystal and into the atmosphere, leaving lower water concentrations near the phenocryst rims. Because we know how fast the water moves, the amount of water loss from the crystal will tell us the timescale of the magma movement. One system we have identified as likely to yield interesting results is from Fuego Volcano, one of the most active volcanoes in Central America. We have obtained phenocrysts of the mineral olivine from Fuego's last major explosive eruption in 1974. We require analyses of the water concentration profiles of these olivines as well as phenocrysts from other volcanic eruptions.

**Analyses required:** This project will require preparing (selecting, orienting, polishing) olivine phenocrysts from the October 17, 1984 eruption of Fuego Volcano in Guatemala and analyzing their water contents by Fourier Transform Infrared spectroscopy (FTIR). Lab work will require 20 hours/week.

**Prerequisites:** None, although some knowledge of chemistry and/or mineralogy a plus.

**Mentors:** Elizabeth Ferriss, ferriss@ldeo.columbia.edu, 845-365-8733,
Terry Plank, plank@ldeo.columbia.edu, 845-365-8410

# How did tropical Pacific Ocean conditions influence El Niño behavior 20,000 years ago during the Last Glacial Maximum?

**Background:** The modern day tropical Pacific Ocean is characterized by a warm pool of water in the west and a cold tongue in the east, setting up a strong east-west temperature gradient. The El Niño-Southern Oscillation (ENSO) generates large-scale changes in this tropical Pacific ocean-atmosphere system, significantly influencing global climate. The thermocline, the uppermost layer of the ocean within which temperature decreases rapidly with depth, plays a critical role in this tropical Pacific temperature pattern and ENSO variability. How the coupling between the thermocline, the tropical Pacific temperature pattern and ENSO will behave under future climate change is largely unknown. Paleoclimate records from the Last Glacial Maximum (LGM) provide insight into the tropical Pacific Ocean conditions and ENSO behavior during periods when global boundary conditions (ice sheet extent, atmospheric partial pressure of CO2) were different from today. This project uses a collection of marine sediment cores from the International Ocean Discovery Program spanning the western and eastern tropical Pacific to reconstruct tropical ocean conditions during the LGM. By using the chemistry of fossil shells found in these marine sediments, we will reconstruct the structure and spatial variability of the thermocline and its relationship to surface conditions and ENSO.

**Analyses Required:** This project will require microscope work to properly identify and sort fossil shells. Laboratory work will include chemically cleaning the shells, preparing shells for analysis and analyzing samples on Inductively Coupled Plasma-Mass Spectrometer (ICP-MS) and stable isotope mass spectrometer. Lab work will require 20 hours/week.

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

**Mentors:** Heather L. Ford, hford@ldeo.columbia.edu, 845-365-8406
Gerald Rustic, grustic@ldeo.columbia.edu, 845-365-8189

# How stable is the Earth's rotation axis?

**Background:** On the human timescale, the Earth rotates around a fixed axis passing through the north and South Pole. However, on 1 to 10 million year (My) timescales, the movement of density structures deep inside the mantle may destabilize the rotational orientation of the Earth. In such a scenario, the entire silicate Earth, consisting of the crust and mantle, would reorient with respect to the rotation axis, resulting in the coherent drift of continents across several up to 60˚ of latitude. This motion, known as True Polar Wander (TPW), potentially results in profound environmental change and sea-level fluctuations at local and global scales.

One of the most recent hypothesized TPW events may have taken place during the Late Jurassic Period (~165-145 Ma), when the Earth rotated ~30˚ clockwise around an axis near modern-day West Africa (Fig. 1). Understanding this and other TPW episodes in the geologic past requires the collection of paleomagnetic data. Because the Earth's magnetic field remains fixed with respect to the rotation axis, TPW is expected to result in a measureable change in the magnetic field direction on all continents.

Paleomagnetic samples from North America, South America, Australia, Europe, and Africa provide tantalizing, but inconclusive, evidence for a major Late Jurassic reorientation of the Earth. We are undertaking further paleomagnetic studies to refine constraints on Late Jurassic TPW, which holds implications for mantle dynamics and the interpretation of climate and sea-level records from the Jurassic.

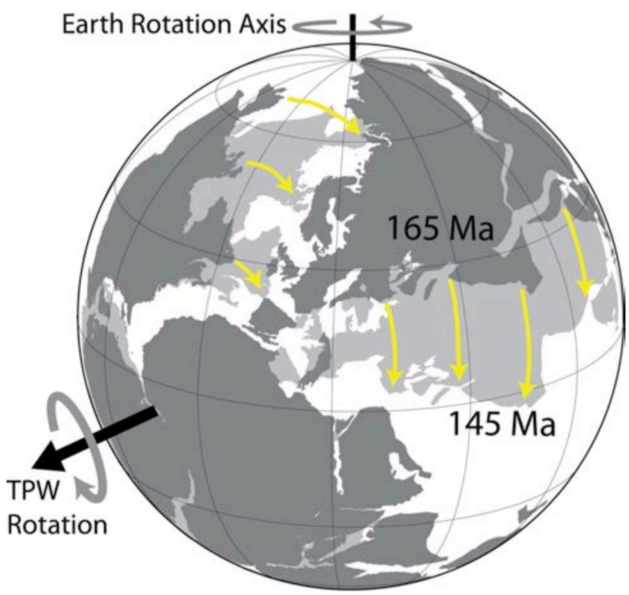



Fig. 1. Reconstructed map of the Jurassic Earth showing True Polar Wander between 165 and 145 Ma. Rotation is based on a global compilation of paleomagnetic data (Kent & Irving 2010, *J. Geophys. Res.* 115, B10103).

**Description of Tasks:** This project will consist primarily of laboratory work and analysis of the acquired data. Two suites of paleomagnetic samples will be processed: (1) volcanics from the La Negra Formation of northern Chile collected during July 2015 (ages 160-155 ma) and (2) tuffs and sediments from the Daohugou beds of North China collected during September 2015 (ages 165-153 Ma). Through these experiences the student will gain familiarity with paleomagnetic methods and the relationship between geophysical forcings, climate, and sea level.

**Prerequisites:** Introductory Earth science preferred.

**Mentors:** Roger Fu (rf2006@ldeo.columbia.edu) and Dennis Kent (dvk@ldeo.columbia.edu)

# How will the combined effects of Hypoxia and Ocean Acidification affect the unusual mixotroph *Noctiluca scintillans* of the Arabia Sea?

**Background**: Our fieldwork in the Arabian Sea (AS) has shown that the northern AS is undergoing a radical ecosystem shift. Diatoms, the ubiquitous, unicellular, siliceous photosynthetic organisms that thrive in the nutrient-rich waters of the winter monsoon have been replaced by an unusual mixotrophic dinoflagellate *Noctiluca scintillans* (NS) (Fig. 1a-c). Our research has shown that NS blooms are facilitated by intrusion of low oxygen waters from AS's 'dead zone' because they can photosynthesize at higher rates and thrive under lower oxygen conditions than diatoms. But hypoxia or the depletion of oxygen caused by excessive organic material and its heterotrophic degradation by microbes also produces excessive $CO_2$. Currently, rising $CO_2$ emissions from human activities are lowering the pH of seawater in a process known as Ocean Acidification. A lowered oceanic pH can restructure marine ecosystems through many processes. Blooms of NS covering vast expanses of the AS for almost 3 months are disrupting the delicate balance of the ecosystem by causing declines in biodiversity and damage to local fisheries. How will NS react to a lowered pH caused by anthropogenic inputs of $CO_2$ as well as from organic matter, a large part of it from domestic and industrial outfall from mega cities bordering the AS? The physiology of this highly complex organism is largely unknown because in the past it was confined to episodic blooms along the coast and bays in the tropics. But recently it has expanded its range and is now a recurring feature in the AS, the Gulf of Oman and Thailand with new reports on the rise.


Fig 1: (a) Dense bloom of NS covering the Arabian Sea (b) Single Cell of NS with its green endosymbionts (c) Close-up of green photosynthesizing endosymbionts inside NS

**Experimental Plan:** We have been able to grow NS in the laboratory; perhaps the only live culture in the world now. This project will use NS cultures to conduct controlled incubation experiments that investigate the combined impact of low oxygen and pH on the ability of NS to survive and grow to bloom proportions over other phytoplankton. NS and diatoms cultured from the AS will be exposed to a range of range of oxygen and pH conditions and growth monitored. Dissolved oxygen, pH, chlorophyll a concentrations, cell counts, variable fluorescence and nutrients will be measured over the course of the experiments using oxygen sensors, FlowCAM imaging system and fast rate repetition fluorometry. Statistical tests will be employed to assess the results.

**Mentors:** Dr. Joaquim Goes (jig@ldeo.columbia.edu) and Dr. Helga do Rosario Gomes (helga@ldeo.columbia.edu)

# How did the Pacific Ocean respond to the Mid-Pleistocene Transition?

**Project Description:** About 900,000 years ago, a shift in Earth's climate called the Mid-Pleistocene Transition (MPT) occurred where glacial cold periods became longer and more intense. After the transition, ice sheets in North America were bigger and glacial temperatures were colder, signaling a major shift in the way the ocean and atmosphere interact to moderate Earth's climate. Much debate still exists on what caused the transition, but many studies suggest that changes in the ocean played a large role. In this project, a student will measure the oxygen isotopes of benthic foraminifera to examine how the deep Pacific Ocean changed across the MPT. The student will analyze these foraminifera from deep-sea sediments recovered in a drilling core from ODP site 805 in the Western Equatorial Pacific Ocean. Foraminifera are small marine protists that make a calcium carbonate shell, and the oxygen isotope ratio ($^{18}O/^{16}O$) of that shell reflects the temperature of the seawater they grew in as well as the total amount of ice that exists on the planet.

Because there are fewer oxygen isotope records from the Pacific Ocean than the Atlantic Ocean, this project will create a record from a vital region for increasing our understanding of the transition. Additionally, there is some debate about the magnitude and timing of changes in Pacific deep sea oxygen isotope records across the MPT. Creating more records from the region will be critical in helping to understand the timing and magnitude of shifts in the Pacific Ocean, which is a major player in the regulation of global climate. Stable oxygen isotopes are also used to create age models for sediment cores, which will also be investigated in this project. Finally, oxygen isotope measurements also yield carbon isotope values, which are a key indicator of ocean circulation and biological productivity changes.

**Analyses**: To prepare samples for stable isotope analyses, sediments will be washed, sieved, and picked for benthic foraminifera. All oxygen isotope samples will then be run at LDEO on the Optima VG Isotope Mass Spectrometer. Data analysis will include spectral analysis and other statistical methods. Finally, data can be compared to the global oxygen isotope stack to construct an age model for the MPT time period.

**Project Supervisor:** Laura Haynes. Email: Laurah@ldeo.columbia.edu Phone: 919-323-140

**Faculty Sponsor:** Bärbel Hönisch

# Where does water come from during extreme droughts in the eastern Mediterranean-Dead Sea? Characterizing Dead Sea water sources

**Background:** Water is a scarce resource in the Middle East, and climate models predict a drier future in a warmer world. The Dead Sea watershed stretches between the Saharan-Arabian desert belt and the more temperate and wetter Mediterranean climate zones, and different paleoclimate proxies in sediments trace the changes in these zones through time. In the Dead Sea (Israel, Jordan, Palestine) salt, mainly halite has precipitated during dry periods of interglacials. The peak of the last interglacial was characterized by the driest period known in that region over the last 200,000 years along with some wetter intervals. During the driest period, some isotopic tracers show drastic shifts that suggest a completely different hydrologic regime compared with today. In order to identify the causes of these shifts, the sources of water and sediment to the Dead Sea have to be identified.

This project aims to characterize the composition of U, Nd, Sr isotopes in water sources and floods entering the Dead Sea, in order to identify changes in the hydrologic regime during periods with very low availability of water and provide answers to the following questions. *What were the water sources during long drought periods? How did rainfall distribute over the year? Were rain storms scarcer but more concentrated? These questions are crucial for future planning and water management in the future warmer Middle East.*

**Methods:** The project involves processing sediment and water samples (crushing, dissolving, chemical separation) in the LDEO clean chemistry lab (4 weeks) and measuring them by ICP-MS and MC-ICP-MS in order to determine isotopic compositions in water and sediment sources around the Dead Sea (2.5 weeks). The remainder of the time will be spent processing the data, combining them with other existing data, and interpreting the paleoclimate implications. This project may be expanded to a senior thesis project, including comparison with climate model data, analyses of the Dead Sea deep drilling core samples and quantitative budgets of isotopes.

**Thesis 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 within two major climate systems: the Saharan–Arabian and the Mediterranean. The figure shows the location of the Dead Sea Deep Drilling Project (DSDDP) site at the center of the modern salt lake, at a water depth of 300m.

A flood entering the Dead Sea creating a plume of fresh water and sediment

# How Much Do Volcanic Eruptions Affect Our Climate? - Evaluating Future Climate Change and Climate Models for the IPCC

**Background**: Large volcanic eruptions, such as the 1991 eruption of Mt. Pinatubo, represent some of the largest short-term disruptions of our climate system. Gaseous volcanic emissions are converted to aerosols -- tiny particles -- that alter the radiation balance of the earth's climate. This summer marks the 25th anniversary the 1991 Mt. Pinatubo event, the strongest eruption of the 20th century. Since 1991, our methods of representing the climate forcing of volcanic emissions have not changed significantly -- all of the eruptions of the historical period are smaller in magnitude than this '91 event. Climate models do a reasonably good job at representing events of this magnitude -- and smaller.

Last year was the 200th anniversary of the 1815 eruption of Mt. Tambora -- an event 3-4 times the size of Mt. Pinatubo. Climate response in observations is generally smaller than that simulated by state-of-the-art climate models. This mismatch has motivated much model development, and a new project specifically focused on the climate impact of larger events.

**Analysis Required**: NASA Goddard Institute for Space Studies has developed a new means of implementing volcanic eruptions that capitalizes on decades of development in implementing climatically important aerosol microphysics in the climate model. The intern will assist us in analyzing and preparing simulations for the upcoming VolMIP (Volcano Model Intercomparison Project), an endorsed CMIP6 experiment. (CMIP is the coordinated suite of experiments done by climate modelers that are used to prepare the 7-yearly IPCC report – the Intergovernmental Panel on Climate Change. This report represents the state-of-knowledge of the entire field of climate research.)

Some relevant reading:
Framing the volcano representation: http://www.pages-igbp.org/products/pages-magazine/6911-23-2-volcanoes-and-climate
VolMIP project: http://www.volmip.org

**Prerequisites**: the intern will do analysis on existing GISS climate model simulations and will set up new simulations. For this reason, it is important that the intern have experience with a programming language (Fortran, C, etc.), and proficiency in a high level scripting language (Python, R, IDL, MatLab).

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

# How old is the ocean floor? A new magnetic polarity time scale for the Late Cretaceous-Eocene

**Background**: Deep time, the immense age of the Earth compared to human history, is one of the major discoveries of geological science. Over the last few decades, geoscientists have refined a geological time scale that assigns numerical ages to the rock record. Key events to date are reversals in the polarity of the Earth's magnetic field, which are recorded globally in magnetic anomalies on the spreading ocean floors (Figure 1). By dating these magnetic field reversals, we can time environmental changes observed in sediment sequences and calibrate chronologies based on astronomical cycles.

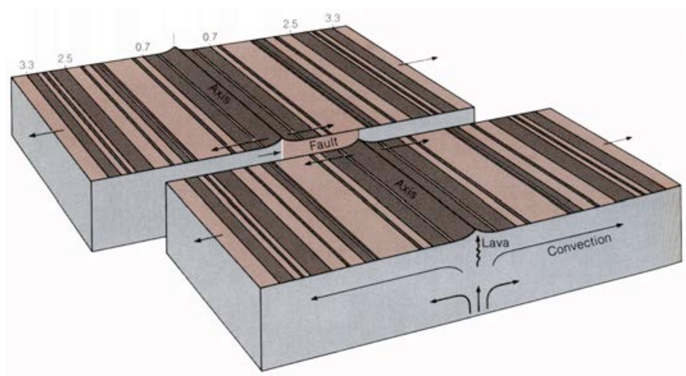



*Figure 1. Like a magnetic tape, oceanic crust created at a mid-ocean ridge records polarity reversals of the magnetic field.*

Magnetic polarity time scales are typically constructed on the basis of magnetic anomalies from a carefully selected spreading center, assuming that the plates moved apart at nearly constant rates. A fundamental drawback is that the time scale should minimize the variability of spreading rates on profiles from different mid-ocean ridges, not just one. This project will apply a new methodology that uses magnetic profiles from multiple spreading centers. The goal is to construct an improved magnetic polarity time scale for the Late Cretaceous-Eocene (~84-34 million years ago).

**Data analysis**: You will be introduced to geological time scale construction with readings and discussions on the history of time scale development, plate tectonics, magnetic reversals, radiometric dating, and astrochronology. In the data analysis, you will first assemble from existing databases marine magnetic anomaly profiles covering different spreading centers. You will then process these data to obtain distances to magnetic reversal boundaries and generate a large sample of time scales that minimize the global variation of spreading rates with a Monte Carlo simulation. You will be provided with Matlab code and will assist in developing it. The final product will be a new magnetic polarity time scale and a quantification of its uncertainty.

**Prerequisites**: An interest in applying quantitative analysis in the natural sciences. Background in earth sciences, plate tectonics, statistics, and programming preferred.

**Thesis mentor**: Alberto Malinverno (alberto@ldeo.columbia.edu).

# 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 collected new earthquake data from 2012 until 2015. 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.

**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)

# What climate conditions promote uncontrollable forest fires in Indonesia?

**Background:** Smoke from forest fires across Indonesia has been choking cities across Southeast Asia for months. The haze poses serious public health and economic risks for the communities throughout the area. Indonesian authorities have been working hard to put out the fires, but have had trouble preventing the fires, which are intentionally set to clear land for agriculture. The fires also pose a global threat. The forests now burning had been growing on, and were contributing to, vast stores of peat—the partially decayed plant material that accumulates where growth is faster than decay. Peatlands (places where peat accumulates) are an important part of the Earth's climate system—they are the primary locations where carbon from the atmosphere is sequestered on land. While they cover only 3% of the land surface, they hold 30% of soil organic carbon. Burning peat releases immense stores of carbon dioxide to the atmosphere, strongly contributing to global warming. Since September, daily $CO_2$ emissions from the fires alone routinely surpass the average daily emissions from the entire US economy.

Emissions from the fires this year are estimated to be 1.62 billion tonnes of $CO_2$, or about 0.44 GtC so far this season, or 0.15% of all the carbon emitted by human activity since the industrial age began. El Niño conditions in the Pacific Ocean have made Indonesia and the rest of Southeast Asia particularly dry, lowering the water tables in the peat forests, making much more of the peat available to burn. Normally, peat does not burn below the water table, where it is water saturated. Further, many places where land is cleared by burning are also drained, artificially lowering water tables even further. What is not known is how often such water-table-lowering events have occurred in the past and how this has affected fire frequency. How often do large fires occur? What climate conditions promote fire and with what frequency do these occur? The aim of this project is to use sediments of a peatland from central Kalimantan, Indonesia, to reconstruct the past climate experienced by the peat forest and link changes in climate with carbon accumulation rates and fire frequency.

**Analysis:** The student will use the abundances and hydrogen isotope ratios of leaf wax biomarkers to create a paleoclimate reconstruction from forest peatland sediments. 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

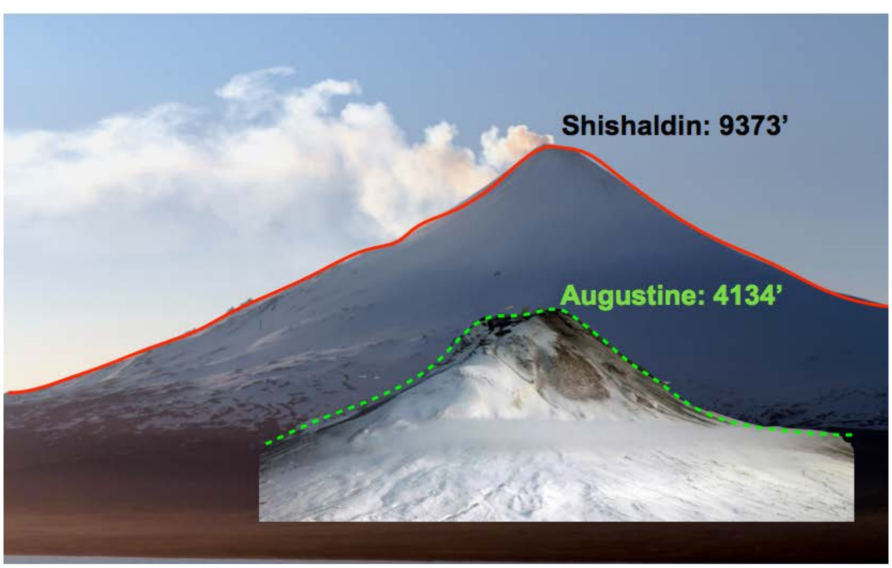
# Why so big? Exploring a correlation between volcano size and chemistry and what it tells us about eruptions

**Background**: Volcanoes are the primary locations where the Earth's mantle transfers heat, gases and magma to the surface and atmosphere. Volcanoes offer a wealth of information about Earth's interior, yet they also present a major natural hazard. Volcanic eruptions come in many types and sizes, ranging from small-scale lava flows (like those commonly occurring in Hawaii) to catastrophic explosive eruptions that can eject thousands of cubic kilometers of ash into the air (such as those that have occurred at Yellowstone). Many factors control the style of volcanic eruptions, including the volume of magma supplied to the volcano, speed of magma ascent, amount of gases trapped in the magma, and composition of the magma. The size of a volcano is a complex outcome of its eruptive history, while the composition of eruptive products give insight into the factors controlling eruptions. This project will explore the relationship between the size and composition of arc volcanoes across the globe to answer the questions: Why are some volcanoes bigger than others? Does volcano size relate to eruptive style?

**Analysis required**: The student will use computer tools such as Matlab and ArcGIS to analyze large datasets of volcano topography, satellite measurements and volcano chemistry from around the world, with a focus on the Aleutian islands of Alaska (see volcano pair below). The student will also conduct chemical analyses on critical volcanic samples recently collected from Aleutian volcanoes that range in size and magma output.

**Prerequisites:** None, although some coursework in Earth Science and an interest in programming would be an asset. Experience with Matlab and ArcGIS is a plus but not required.

**Mentors:** Terry Plank: tplank@ldeo.columbia.edu, Dan Rasmussen: danielr@ldeo.columbia.edu , Einat Lev: einatlev@ldeo.columbia.edu



# It's getting hot in here: Do biomarkers in sediments under lava flows record a thermal diffusion profile?

**Background:** Sediments in the Earth often undergo dramatic heating as a result of various processes including frictional heating during earthquakes, burial, and exposure to flowing lava from a volcanic eruption. The thermal alteration of biomarkers has been used as an indicator of the temperature rise experienced by the sediment. Recent work at LDEO has used the thermal alteration of biomarkers to determine which faults have slipped during earthquakes (where high slip velocities lead to high temperature rises). By running heating experiments on sediments with similar biomarker compositions, we can determine the rate at which these biomarker thermal alterations occur (biomarker kinetics). Using the biomarker kinetics, we can estimate the temperature rise and the stress state on a fault during an earthquake.

However, experiments constraining biomarker kinetics have been limited to low temperatures relative to those attained by faults during seismic slip. In addition, this method has not been applied to sediments exposed to temperatures nearly high enough to melt rock in other geologic environments (e.g. sediments exposed to high velocity slip during an earthquake, sediments under lava flows or sediments surrounding impact-related melt).

We will run lava flow experiments over sediments from ocean drill cores to simulate the heating expected in these kinds of settings. We will measure changes in the concentration of biomarkers in the sediment from these experiments to determine whether they record a profile of thermal diffusion away from the heated surface.

**Analysis Required:** The student will participate in a lava flow experiment at Syracuse University in which we will place sediment from ocean drill cores (which have been previously used to calibrate the kinetics of biomarker thermal maturity) underneath the flowing lava. The student will then work in the Organic Geochemistry Lab at LDEO to extract the organic material from the sediment and characterize the biomarker content with distance from the lava flow surface.

**Prerequisites:** None, though previous knowledge of organic chemistry is a plus.

**Mentors:** Hannah Rabinowitz (hannahr@ldeo.columbia.edu); Einat Lev (einatlev@ldeo.columbia.edu)

# How Does Lava Interact with Objects?
# An Investigation Through Laboratory Analogs

**Background:** Lava flows pose a significant hazard for communities living near active volcanoes. They can destroy buildings, create forest fires, damage water and electricity resources, and cut off roads needed for day-to-day use and emergency access. As scientists, we are concerned with how lava flows impact property and infrastructure and with the fluid mechanics that drive lava flow emplacement. At the new Fluid Mechanics Lab at LDEO we have set up experiments that simulate natural lava flows using analog materials, including corn syrup and polyethylene glycol (PEG) wax. We will use this laboratory setup to investigate how lava flows interact with manmade and natural objects such as buildings, roads, forests, and rivers. The experimental results will teach us if and how barriers can be used to influence the emplacement of a lava flow away from a specific site, and how flow prediction models should account for emplacement conditions such as topography and vegetation.

**Project Expectations:** This project will require about 20 hours per week of laboratory work at the Fluid Mechanics Lab. The student will build model substrates that include scaled versions of objects and will run experiments under the guidance of the mentors. The student will spend the rest of their time analyzing data through video analysis, photogrammetry, and comparison of experimental results to natural lava flows and previous experiments.

**Prerequisites:** None, however knowledge of Excel and/or MATLAB is a plus.

**Mentors:** Elise Rumpf, erumpf@ldeo.columbia.edu, 808-366-8970
Einat Lev, einatlev@ldeo.columbia.edu

A lava flow experiment using dyed corn syrup at the Fluid Mechanics Lab at LDEO. Here, we were investigating how lava is emplaced on a boulder field.

# How does future climate change in the western North America affect ecosystems and water management?

**Background**: Over recent decades western North America has experienced serious changes in climate due to both changes in radiative forcing and natural variability. These changes include widespread warming, serious and prolonged droughts, reduced snow pack and earlier snow melt. All are associated with impacts in water resources, agriculture, rangelands and natural ecosystems. Climate model projections of widespread warming and decreasing precipitation over southwest North America suggest increasing climate stress ahead. Consequently, climate variability and change is being seen as a major stressor for long-term land management of ecosystems and water resources in planning for the future and to adapt to changing conditions. Ecosystem and land managers in the western U.S. are concerned that climate change is causing changes and spatial shifts in eco-regions posing challenges for conservation and management. Thus the proposed work will focus broadly on large-scale climate features across western North America, and the implications of changes in these features for policy and management in application sectors. Depending on student interest, work might be purely on management-relevant climate or combine analyses of climate variations with impacts on water, land and ecology.

**Analysis Required**: This project will require analysis of large climate data set from both instrumental observations and climate model outputs using the IRI data library and "ingrid" - a web-based analysis and mapping tool.

**Prerequisites**: Basic college level statistics will be helpful, but not required. Programming familiarity and skill (Matlab, Ingrid, Python, R for example) is required.

**Thesis Mentors**: Richard Seager:seager@ldeo.columbia.edu, 845-365-8743 , Mingfang Ting: ting@ldeo.columbia.edu, 845-365-8374, Yochanan Kushnir: kushnir@ldeo.columbia.edu, 845-365-8669

# How do Transform Faults Evolve and How Does Continental Structure Affect Them?

**Background**: The North Anatolian Fault (NAF), a continental transform fault, slices across northern Turkey before splintering into several branches as it approaches the Marmara Sea and the megacity of Istanbul. In the 20$^{th}$ century, the NAF ruptured in a series of earthquakes with the most recent being the 1999 M7.4 Izmit earthquake at the edge of the Marmara Sea. The Marmara Sea now remains as the last seismic gap along the fault. Near the Marmara Sea, the NAF splits into several branches and adds a component of extension, which produces the subsidence of the Marmara Sea. Most of the strain is associated with the Northern Branch, which has spawned three 1200-m deep basins along it. It has been proposed that the strain is focusing on the Northern Branch and that the Central and Southern branches are being abandoned. This concept fits with the hypothesis that continental transforms originate as a distributed network of small faults with complex geometries that, with continued slip, gradually coalesce and simplify into a through-going fault. However, recent multichannel, sparker, and chirp seismic reflection and multibeam bathymetry data demonstrate continued activity of the Central Branch.

**Analysis Required**: New data collected in 2013 and 2014 image the stratigraphy and numerous individual fault strands on the southern shelf of the Marmara Sea. The intern will use these data, in combination with a large suite of available previous data, to help map the stratigraphy and faulting related to the Central Branch of the NAF. Based on this stratigraphic framework, we will evaluate fault kinematics of many strands over the southern Marmara Sea during the last several million years. These data will contribute to the investigation of fundamental questions about transform fault systems and estimates of the seismic hazard. By comparing the temporal record of slip on the Northern and Central branches and other faults in Marmara, we can test models for fault interaction currently debated for the NAF and other transforms. The Northern Branch is relatively continuous and single stranded while the Central Branch is discontinuous and multi-stranded. By contrasting the slip history of these branches, we will resolve whether their different accumulated slip can fully account for these different fault properties or whether they are also influenced by pre-existing structure.

**Prerequisites**: None, some experience with stratigraphy or structural geology a plus. Will spend a lot of time interpreting seismic data on computer.

**Mentors**: Michael S. Steckler: steckler@ldeo.columbia.edu and Céline Grall: cgrall@ldeo.columbia.edu

# How are Marine Microbial Communities Affected by Climate Change and Land Use Changes?

**Background**: This project is an exploration of the key physical and biogeochemical processes that control eutrophication and that may lead to ecosystem changes in the coastal waters of the South China Sea (SCS). The SCS is a marginal sea adjacent to a region of rapid land use change and is strongly influenced by riverine inputs, including a seasonal offshore jet that transports the Mekong River plume well offshore. These factors make it an excellent model system for studying terrestrial-oceanic linkages, nutrient dynamics, and the potential impact of land use change on marine ecosystems. Seitzinger et al (2005) found that about 30% of the global particulate organic carbon (POC) flux from the land to the ocean occurs in Southeast Asia as a consequence of high runoff and anthropogenic activity. Modulation of runoff by dam construction may change this contribution to the global POC flux on short time scales.

**Analysis required**: The intern will be involved in a three-week field project carried out on the R/V Falkor in June 2016. The field research done by the student will focus on characterizing the microbial community using a variety of sampling techniques and obtaining bio-optical data that can be used to validate satellite derived measurements. This work will complement other investigations carried out onboard to characterize the nutrient load carried by the Mekong in the context of the hydrography and biogeochemistry of the SCS and will allow us to constrain the role of different forcings in supporting production. The work area will include environments with significant inputs from the Mekong River as well as oligotrophic regions close to shore and affected by the plume. The cruise will last three weeks, allowing us to conduct thorough surveys and intensive experiments. We will carry out a standard suite of basic physical (T, S), chemical (nutrients), and biological (community biomass and composition) measurements using samples collected with Niskin bottles. The student will be involved in collecting water samples from the Niskin bottles and using a flow-cytometer to estimate the abundance of picocyanobacteria *Synechococcus* and *Prochlorococcus* which can be used to trace the transition from typical coastal (Syn-dominated) to offshore (Pro-dominated) communities and to link the riverine influence to the major primary producers in the system. The student will be exposed a range of interdisciplinary activities and will have the opportunity to interact with scientists and students from other institutions in the US, Germany, Sweden, and Vietnam.

**Prerequisites**: The fieldwork involved can be physically and mentally demanding. The student should demonstrate ability to work in a team. Biology or Chemistry majors with quantitative skills and prior field and laboratory work experience preferred.

**Mentors**: Ajit Subramaniam [ajit@ldeo.columbia.edu](mailto:ajit@ldeo.columbia.edu)

# What Lies Beneath? Geological Mapping under the Largest Ice Shelf on Earth

**Background**: The Ross Ice Shelf, the size of France is the largest ice shelf currently on our planet. In November 2015 the ROSETTA-ICE Team, lead by Lamont scientists and engineers collected the first comprehensive data set capable of looking at both how the ice shelf is changing and what the underlying geology is like. Ice shelves are the floating extensions of the Antarctic Ice Sheet and are where most of its mass loss occurs, by iceberg calving and basal melting. For a steady-state ice shelf, mass loss balances the mass gained through ice inflow across the grounding line and net surface accumulation from local snowfall. Changes in an ice shelf will occur when any of these mass budget terms change. As ice shelves are already floating, changing their mass does not directly influence sea level. However, ice shelves provide a backstress on the surrounding grounded ice, a process known as "buttressing". A reduction in backstress, through reduced lateral stresses or release of a thinning ice shelf from ice rises and other pinning points may accelerate flow rates of grounded ice to the ocean. The Ross Ice Shelf contributes to buttressing of the Siple Coast ice streams, and major East Antarctic outlet glaciers.

**Analysis Required**: This project will use the newly acquired airborne magnetics data over the Ross Ice Shelf to map the thickness of sediments in the rift basins beneath the Ross Ice Shelf. We will use a Werner inversion technique to infer sediment thicknesses. The distribution of the sediments will be important for understanding both the waxing and waning of the ice sheet in the past as well as the formation of the Transantarctic Mountains. The intern will work with the magnetics data using a widely used potential field software program GeoSoft. Using this PC based environment the goal will be to map the sediment thickness, the bounding faults and possibly the distribution of submarine volcanics.

**Prerequisites**: Intense interest in geology, geophysics and mathematical techniques. A minimum of three semesters of physics and/or differential equations.

**Mentors**: Kirsty Tinto tinto@ldeo.columbia.edu and Robin Bell robinb@ldeo.columbia.edu

# How does the monsoon cycle affect weathering and erosion of the Himalayas?

**Background**: The uplift and erosion of the Himalayan mountains has cooled global climate over the last ~40 million years through the process of silicate weathering, which draws down $CO_2$ from the atmosphere. Monsoon rainfall plays a role in weathering and erosion of the Himalayas, and the strength of the monsoon varies on a ~23 thousand year (precessional) cycle. How much does the monsoon cycle affect erosion and weathering, and does this play a role in the global $CO_2$ cycle? Here we look for clues to address these questions.

In this project we will work on marine sediments from the Bengal Fan, collected in spring 2015 on IODP Expedition 354 to the Bay of Bengal in the Indian Ocean. The fan is made of muds and sands that come from the Himalayas via weathering, erosion, and transport along rivers and submarine channels. These sediments preserve a history of Himalayan erosion and the broad aim of the expedition was to understand relations between the mountains, the monsoon, and climate change. Expedition Site U1452 contained a sediment record of the last ~200 kyr and had a distinct precessional cycle in lithology.

We will measure K/Ar and $^{40}Ar/^{39}Ar$ thermochronological ages of the Site U1452 sediments; these ages depend on the erosion rate and type of weathering. We can also measure U-series isotope concentrations, specifically $^{238}U$ and $^{234}U$, for comminution dating, which is the age at which the sediment components were ground to a fine grain size. Combined with the depositional age, and under favorable conditions, the sediment transport and residence time can be determined by the U-series comminution method.

**Analysis Required**: On about 10-20 sediment samples from IODP Hole U1452C, Bengal Fan: 1. sieve to separate out the coarse fractions (sand, >63 and >150 microns); 2. examine the mineralogy of the >150 micron fraction under light microscope and separate out hornblende and biotite mineral grains for $^{40}Ar/^{39}Ar$ analysis; 3. further divide the fine grain size fraction (silt and clay size, <63 microns) by settling in water and siphoning off the finer suspended sediments. The resulting sub-samples will be measured for argon and uranium isotopes on mass spectrometers in LDEO's geochemistry building.

**Prerequisites**: There are no prerequisites, but coursework or previous research using geochemistry is an advantage. A sense of precision and a steady hand are also helpful.

**Mentors**: Trevor Williams: trevor@ldeo.columia.edu, Sidney Hemming: sidney@ldeo.columbia.edu, 845-365-8417