How Does Climate Change and Soil Composition Affect the Arsenic and Nutrient Content of Rice?

Background: Arsenic is a common environmental pollutant whose chemical behavior is poorly understood because of its multiple oxidation states and chemical affinities. Arsenic can appear at unsafe levels in groundwater, soil and food in both the developing and developed world. Arsenic is often abundant in rice because of the physiology of rice plants, and the unique environments typical of rice production. In many cases, the exposure to this arsenic in food is believed to represent the largest source of arsenic to humans, and, potentially, a major human health risk to people who depend on that rice as a staple. Rice consumption is also tied to human nutrient deficiencies of iron and zinc, in part because of diets common of rice consumers. In many cases, it appears that changes in water availability and nutrient status can affect arsenic levels considerably, and potentially result in food that is either less nutritious or even unhealthy to consume. This project will involve studying the chemical forms and concentrations of arsenic and other metals in soils, groundwater and in rice grown on that soil in order to better define the chemical pathways through which arsenic affects food and groundwater. The study will also include differing temperatures of growth to better define how arsenics chemistry in soil, water and plants will change as the climate grows warmer.

Analysis Required: Much of the research (at least 20 h/week) will involve experiments with plants in a garden or greenhouse, and lab work to chemically analyze plant, soil and water compositions under differing conditions. These chemical experiments could continue into the following term, potentially as a thesis project for the student. Complementary X-ray diffraction and synchrotron studies will provide estimates of the oxidation state and chemical affinity of the arsenic. The balance of the time will be used to analyze data and to model results based on potential changes in climate using either Excel or the R programming platform.

Prerequisites: General chemistry, an interest in Earth or Agricultural Sciences and lab courses are required; experience in excel or R Studio would be ideal.

Mentors: Benjamín Bostick, bostick@ldeo.columbia.edu, 845-365-8659.

What Can Corals Tell Us About Hydroclimate in Panamá to Improve Panamá Canal Management?

Background: Rivers and precipitation play a critical role in tropical ecosystems as they are tightly coupled to climate and have significant influence over human societies via drinking water, food security, and economics. In Panamá, these relationships are ever present when we consider the regional and global impacts of the functioning of the Panamá Canal. Precipitation and river discharge (Q) are strongly linked in Panamá. Rainfall totals across Panamá consistently place it in the top five countries for annual rainfall, with a pronounced wet season lasting from May to November. Refining predictions of how precipitation and Q, collectively hydroclimate, will evolve in Panamá over the course of impending warming is of the utmost importance to the operation of the Panamá Canal. Recent droughts have resulted in significant shipping restrictions beyond those typically associated with the annual dry season.

Q records are notoriously short-lived and reliable instrumental rainfall data is temporally limited. To fully understand the recurrence interval of drought and variability in Q, particularly prior to human influence on climate, we must look beyond the instrumental and historical records. Instead, we will analyze the geochemical composition of coral skeletons. Subtleties of the calcium carbonate structure are dictated by changes in climate and therefore become a recorder of the conditions in which the coral grew. We will study variability in the oxygen isotopes that comprise the coral skeleton over 100 years of growth with near monthly resolution. The oxygen isotope ratio varies based on changes in both sea surface temperature and local salinity, serving as a proxy for these aspects of climate. With the oxygen isotope-derived record of salinity we can determine when the region was plagued by drought. Determining the frequency of drought will improve our ability to determine how often the Panama Canal will be affected.

Analysis Required: The summer intern will generate a stable oxygen isotope record from a coral core collected from the Gulf of Chiriquí, Panamá. The intern will clean coral slabs, drill coral powder with a small hand-held rotary tool, prepare samples for geochemical analysis and assist in measurement of stable isotopes via an Isotope Ratio Mass Spectrometer (IRMS). Work will take place at Barnard College and at LDEO. This project offers the opportunity to learn about and apply the skills necessary for analysis of a paleoclimate proxy. The intern will gain skills in carbonate sampling methods and geochemistry, both of which are widely applicable in many areas of Earth science.

Prerequisites: There are no specific laboratory skills required, all training will be provided. The intern should have an interest in lab tasks, climate studies, geochemistry, or past environmental change. Classwork that covers these topics is ideal but not a requirement.

Mentor: Logan Brenner, lbrenner@barnard.edu, lbrenner@ldeo.columbia.edu

Can Carbon Monoxide Monitors Predict Levels of Black Carbon Exposure from Cooking at Home?

Background: Approximately 3 billion people rely on inefficient combustion of solid fuels for cooking, often in poorly vented cooking areas resulting in both chronic and acute exposures. At the same time, large variations in personal behavior during cooking and vertical and horizontal concentration gradients make personal exposure assessment approaches critical for accurate estimates of exposure to this source of household air pollution (HAP) in health studies. Fine particulate matter ($PM_{2.5}$) is considered the best proxy for overall exposure to HAP; however, the cost of carrying out accurate filter based measurements has resulted in many groups relying on less expensive carbon monoxide measurement with a subset also measurement fine particulate matter. Although initial studies suggested this approach was suitable, several studies have shown poor results for estimating $PM_{2.5}$ exposure from CO. Black carbon (BC) is a major component of $PM_{2.5}$ produced from incomplete combustion of carbon-based fuels including solid fuels used in cookstoves. In a large randomized trial of cookstove interventions in rural Ghana, personal CO monitors were deployed for 72 hrs. on women 4 times during pregnancy and 3 times during the first year of a baby's life together with a large data base of daily questionnaire data. $PM_{2.5}$ monitors were deployed in a subset set of the deployments. GIS data are also available for home location and distance to major trucking routes. Initial investigation suggested CO is a poor predictor of $PM_{2.5}$ in this setting.

Analysis Required: In the summer internship, the hypothesis will be tested that BC levels will be predicted better than $PM_{2.5}$ from co-deployed personal CO monitors. The student will make optical measurements of BC and brown carbon on the archived filters and then carry out modeling of a portion of the data (training set) and then see how well the resulting model predicts the BC levels in the rest of the samples (validation set). Linear regression models will be followed by machine learning approaches if there is time.

Prerequisites: It would be a plus to have prior lab experience, a physics course that included optics (light transmission), and knowledge of R or equivalent programming language.

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How Often Should We Expect Extreme Pollution Events Over India?

Background: Air pollution in Northern India varies with relative humidity, wind speed, boundary layer height, and the strength of near-surface temperature inversions (which prevent air from ventilating, allowing pollution to accumulate in surface air). Although meteorology and air pollution vary from year-to-year, the extent to which air pollution events vary over India is largely unknown, mainly because we lack both long-term observations and model simulations over this region. Furthermore, while we know that air pollution has increased dramatically as emissions have risen in recent years, we do not know how much meteorological factors may be changing as the planet warms. A set of model simulations that we are conducting now provide a novel opportunity to examine air pollution over India and its changes over the last 60 years. We will have at least 5 but possibly as many as 12 ensemble members available for analysis, where each ensemble member varies only in its initial atmospheric state. The same air pollutant emissions and greenhouse gas concentrations are applied to each ensemble member. We envision addressing three related questions: (1) Are extreme pollution events associated with a specific type of weather? (2) How much does climate variability influence the number of pollution events that occur in any given year? (3) How have increasing anthropogenic emissions of air pollutants and greenhouse gases over the 20^{th} century changed the frequency of extreme pollution events over India?

Anticipated tasks: The intern will analyze fine particulate matter over India using a set of chemistry-climate simulations we are currently generating with the National Center for Atmospheric Research (NCAR) climate model with full atmospheric chemistry in the troposphere and stratosphere (CESM/WACCM6) from 1950 to 2014. The intern will explore connections between weather and air pollution over India in a few ways to address the questions above: (1) examine the meteorology during the top 5% of air pollution levels for the last decade in each ensemble member; (2) examine the extent to which the air pollution levels vary during the top 5% of events across the different simulations, and attempt to link these differences to particular meteorological factors; (3) select one meteorological variable, or one set of meteorological factors, and examine the changes over the 20^{th} century.

Skills required: A lab science class is required. Some prior coding experience in Python, R or MatLab, and/or experience working with different file formats and analyzing data will be essential for this project. Communication skills are highly valued for thoroughly documenting codes and disseminating scientific findings.

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What Are the Impacts on Marine Bivalves of the Microplastics in Long Island Sound Waters?

Background: Microbeads, microfibers and micro-fragments are synthetic polymer particles that have found extensive use in industrial and home cleaning products. Microbeads have for long been used in cosmetic and personal care products but their use in these industries has been banned. Micro-fragments are produced primarily as a result of the breakdown of larger plastics, while the largest source of microfibers is believed to be clothing. Most of these microplastics are made of polymers that are not easily degraded and can be potentially toxic to marine life. They enter the aquatic environment primarily through effluent release from wastewater treatment plants because their small size precludes their capture by filtration systems in these plants. Recent studies have shown that microbeads and microplastics are capable of concentrating a wide variety of toxic organic compounds found in waste treatment plants, and can therefore serve as efficient vectors for dispersal of pollutants. However, efforts to assess their ecological risks have been frustrated by their small size and lack of adequate techniques to quantify their distribution in seawater.

Our central hypothesis is that microplastic particles are more widespread than previously recognized and represent a significant threat for commercially harvested bivalves and human health. Students will take part in field sample collections on Long Island Sounding for mapping and determination of hot-spots of microplastics using newly developed imaging and polymer characterization techniques. We will also undertake exposure/response experiments with bivalves to examine whether the ingestion of microplastic is a selective or non-selective feeding process.

Skills Required: Background in Biology and a passion for the environment. Prior work experience in a laboratory setting and commitment to be fully immersed in the project would be big pluses

Mentors: Joaquim Goes (jig@ldeo.columbia.edu)
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Can Clays Supply Carbon for Microbial Growth and Increase Arsenic in Groundwater?

Background: In Bangladesh geogenic arsenic is naturally released from the sediment to the groundwater in shallow aquifers. Shallow Holocene aquifers can have high arsenic levels whereas deeper Pleistocene wells typically have lower arsenic. This source of low arsenic water is fortuitous and provides a clean drinking water source. However, in many areas the shallow and deep aquifers are separated by clay layers. These clay layers were thought to be protective by slowing downward vertical transport of arsenic and organic carbon. Now, with deep pumping occurring in many areas, the depressurization of the deep aquifers can cause the clay layers to become leaky. Underneath the clay layers increased arsenic is sometimes observed. Where is this arsenic coming from? One hypothesis is that the clays leak organic carbon which then causes the mobilization of arsenic within the aquifers. Thus, clean aquifers might become contaminated. The goal of the summer work is to use radiocarbon and sequencing analysis of RNA to test this hypothesis. We have collected filters for RNA analysis from an aquifer below a Pleistocene clay layer. The goal of the summer will be to extract RNA from the filters for molecular and radiocarbon analysis. You will be involved in all aspects of the sample preparation and analysis.

Analysis Required: The project will require you to use geochemical and biological methods in the lab. We will teach you all the methods you need, you just need to be willing to learn.

Prerequisites: None. But chemistry and biology labs are a plus along with experience with Excel.

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Figure 1. Field Site M from Araihazar in Bangladesh. This is two wells from the Pleistocene aquifer beneath the clay being filtered for RNA.

How Are Changing Climate and Environment Expressed in the Last 3000 Years of Vegetational History of Cedar Swamp in High Point, New Jersey?

Background: Cedar Swamp in High Point State Park, New Jersey, is an unusual high elevation bog in New Jersey that was initially investigated by Niering (l953) and then by K. Buhler and D. Peteet in 2016. A macrofossil diagram was generated from the base of the 6.5 m core up to 2.5 meters, when time ran out for the analysis to be completed. We would like to complete this 13,000 year record using loss-on-ignition (LOI) and plant macrofossil analysis to understand the sequence of vegetational change in the last several thousand years. The records will be put together along with a pollen record from the site, and a paper submitted for publication.

Analysis Required: Loss-on-ignition of sediments using balance and ovens. Macrofossil analysis using water, brass screens, low-power microscope, and books and reference seed collection. The site will be also be visited for modern plant collection.

Prerequisites: some Biology, interest in plant macrofossils, previous microscope work

Mentor: Dorothy Peteet, peteet@ldeo.columbia.edu

How Well Do Satellites Capture Flood Damage as Reported in Online News Media in Bangladesh?

Background: Floods affect more people than any other natural disaster and are expected to double with 1.5 degrees of warming by 2030. Climate vulnerable populations in countries like Bangladesh urgently need financial protection from extreme floods to protect economic development and mitigate mass migration. Flood insurance can prevent poverty traps by preventing the sale of critical livelihood assets and enabling continued investments in sustainable development. Index based, or parametric insurance, has emerged as a way to make climate insurance affordable to the poor and financially sustainable to insurance companies. Index based insurance is typically based on proxies like satellite observations that correlate with damage experienced by the client (in this case, a farmer). Quantifying the uncertainty of the proxy data with ground reference data is essential to correctly price insurance, and to ensure that the client and insurer agree on the risk. However, high quality, flood damage data is difficult to access in Bangladesh, because official government data may be biased by overreporting (for those who want to access more relief support) or underreporting in remote areas. Inadequate flood damage data is an obstacle to quantifying uncertainty of satellite data and assessing its ability to serve as a proxy for insurers.

Analysis: This project will develop a spatial time series database of flood damage, focusing on agricultural damage, for river, monsoon, and flash floods in Bangladesh. We will use online media and LexisNexis (online media database) searches to translate articles from Bangla to English, and code the location, date, and damage reported by the flood in a spreadsheet. Depending on student experience, we may attempt natural language processing or other machine learning or text mining approaches to generate a larger number of observations from the GDELT (Global Database of Events, Language, and Tone). We will also use statistics to assess the quality of the time series media data (representativeness analysis from Schmill et al 2014). The first half of this project will focus on collecting and coding media data, and the second half doing statistics and data analysis on the time series. The data produced from this project will be used to compare media time series to crowdsources farmer reports of “bad years” of flooding, satellite flood observations, streamflow, and rainfall data.

Prerequisites: Basic data analysis in excel required. Experience with data analysis, Natural Language Processing, SQL queries, reading Bangla, or experience with media content analysis (coding) a plus.

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