How Does the Chemistry of Rice Paddy Pore Water Influence Human Health?

Background: Rice is the most eaten food on earth, representing more than 20% of calories consumed by humans. Rice is usually grown in rice paddies, which are transiently flooded fields. These conditions in soils modify the chemical environment in the soils, creating dissolved sulfide, methane and arsenic. These species can affect plant growth and yield; they decrease plant growth and yield. For more than 5 billion people, their primary source of arsenic exposure is from rice, which can accumulate the arsenic from porewater. Because the biological processes that affect iron, sulfur and arsenic in soils are modulated by flooding and temperature, they also are highly susceptible to climate change and variability. This project has two goals: (1) it seeks to understand how the redox processes in soils affect pore water chemistry, and thus affect arsenic levels in rice. (2) to evaluate the potential effects of climate on rice production and nutritional status. To do so, we will analyze soil, plant and grain samples from Cambodia and Vietnam from rice plants grown under different conditions. We also will monitor changes in pore water chemistry and redox state in pot experiments in which we grow rice under controlled (greenhouse) conditions.

We hypothesize that sulfide formation in soils is key to arsenic dissolution into porewater and accumulation in rice grains. We have samples from multiple crop years, including this year, that will be invaluable to unravel the effects of climate on growth. This year has been exceptionally wet, and likely to have much more sulfide formation as a result. By working with farmers to understand how they grow rice, and how they responded to this climate shift, we hope to develop strategies to improve climate resilience and lower arsenic concentrations in rice while maintaining rice yields.

Analysis Required: This project requires knowledge of chemical speciation, a combination of oxidation state, mineralogy and chemical species, of iron, sulfur and arsenic. To do so, this project will analyze plant and soil samples with a variety of analytical methods ranging from X-ray Fluorescence microscopy, X-ray absorption spectroscopy, Raman and IR microscopy. These tools are powerful probes of oxidation state and atomic structure that can be used on thin sections collected from agricultural soils whose iron and other isotopic composition is known and whose depositional environment is understood from detailed stratigraphic analysis. Lab work will average 30 hrs. /wk., with the rest of the time being focused on data analysis, literature review, and group activities etc. We also plan to compare data from samples collected in New York City.

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

Mentors: Benjamin Bostick, bostick@ldeo.columbia.edu, 845-365-8659
Magdaly Sevilla, msevilla@ldeo.columbia.edu

How Do Weather Extremes and Upper-Air Patterns Connect with Billion-Dollar Disasters?

Background: Extremes in the U.S. take devastating forms, from intense floods to prolonged droughts that fuel catastrophic wildfires causing billions in property damage, widespread economic disruption, and even tragic loss of life. These high-impact events are often driven by persistent large-scale atmospheric circulation patterns known as North American Weather Regimes. This research project will uncover and quantify these critical links using reanalysis and precipitation datasets, providing actionable insights into the predictability and societal impacts of extreme weather across the United States.

Analysis Required: Here is key analysis required for this project;

1) Data collection (observational and reanalysis (ERA5/NCEP-NCAR) for different climate variables),
2) Identify the main North American weather regimes using ERA5 or NCEP-NCAR reanalysis data (e.g., via self-organizing maps or k-means clustering on 500 hPa geopotential height),
3) Quantify the frequency and intensity of daily precipitation extremes (e.g., 95th/99th percentiles or Rx1day/Rx5day) during each regime using gridded datasets,
4) Assess regional differences in extreme precipitation response to different regimes,
5) Summarize findings in a clear and accessible manner for presentation and publication.

Prerequisites: Understanding of fundamental principles of climate science is essential. Knowledge of Climate data is a plus. Proficiency in statistical methods and data science techniques is necessary. Interpreting results is critical. Proficiency and experience in Python is a must.

Mentor: Muhammad Azhar Ehsan,mae2171@columbia.edu
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What Are the Metabolic Secrets of A Bloom-Forming Mixotroph, *Noctiluca Scintillans*?

Background: The Arabian Sea has undergone one of the most dramatic ecosystem transformations observed in the global ocean, shifting within the past two decades from diatom- and dinoflagellate-dominated communities to widespread blooms of the mixotrophic dinoflagellate *Noctiluca scintillans*. Unlike most phytoplankton, *Noctiluca* relies on photosynthetic endosymbionts while simultaneously competing for nutrients and grazing on other phytoplankton, allowing it to dominate under changing environmental conditions. These blooms are not efficiently transferred to higher trophic levels and pose a growing threat to regional fisheries, particularly along the coast of Oman where intense blooms coincide with peak productivity seasons. Despite its increasing ecological importance, the physiological mechanisms underlying *Noctiluca's* success remain poorly understood.

Work Required: As part of this project students will work with a laboratory strain of Noctiluca scintillans to quantify respiration and photosynthetic rates to better constrain its metabolic balance and growth strategies. By linking metabolic traits to bloom dynamics, this research will provide critical insights into why *Noctiluca* blooms are expanding in the Arabian Sea and how anthropogenic and climate-driven changes are reshaping marine food webs.

Prerequisites: Interest in experimental biology and in complex questions about the harm we humans are causing to our planet.

Mentor: Joachim Goes, jig@ldeo.columbia.edu

What are the Hydrologic Thresholds that Drive Human Migration from Peru's High Mountain Communities?

Background: Climate change is affecting food and water security through changes in precipitation, temperature, glaciated landcover, and droughts patterns (Calvin et al., 2023). Changes in food and water security driven by climate change are having cascading consequences on human wellbeing, particularly in areas where humans are directly dependent on the environment for their livelihoods and subsistence (Bergmann, 2024; Goulden, 2006). In communities with high resource dependence, ongoing work has tied resource insecurity to human migration (Hoffmann et al., 2020; Oakes et al., 2023). However, climate indicators alone are not enough to understand vulnerability and adaptation pathways. While there is evidence that changes in water availability have influenced past shifts in population distribution (Rigaud et al., 2018; Zaveri et al., 2021), there is a critical lack of understanding about hydrologic thresholds and how they interact with socio-ecological systems to drive migration (Xu & Famiglietti, 2023). As noted in the IPCC High Mountain Special Report, there is emerging evidence of connections between changes in the cryosphere (snow and ice processes) and migration in Andean high mountain environments (Hock et al., 2019); however, no research has been undertaken on this from a combined hydrological and socio-ecological systems perspective (Brandt et al., 2016; Carey et al., 2017; Gray & Wise, 2016). The overarching objective is to establish a connection between hydrologic processes in the cryosphere and high elevation to lowland migration at a regional scale, with the main research question being: what are the critical regional hydrologic thresholds beyond which people move in the Peruvian Andes region? We will answer this using a cryosphere model, remote sensing data, interviews, and stakeholder engagement.

Work Required: The intern will focus on data cleaning and analysis of both social (i.e., interview and survey data) and physical data (i.e., runoff from glaciers and snow). Additionally, the intern may have the opportunity to support field work in Peru during the summer.

Mentors: Rebecca Gustine, rgustine@ldeo.columbia.edu
Joerg Schaefer, schaefer@ldeo.columbia.edu

What Do Labrador Sea Aerosols Tell Us About the Extent and Impact of the 2025 Canadian Wildfires?

Background: In the summer of 2025, wildfires tore through 8.9 million hectares in Canada, the second worst wildfire season on record in Canada. Wildfires generate smoke containing high levels of black carbon and toxic metals. We seek to characterize the physical and chemical properties of the terrigenous particulates in samples obtained from the Labrador Sea during summer 2025. Using terrigenous material from sediment core-tops as the "background" terrigenous loading, and by analyzing biomass burning makers (e.g., K, black carbon) in aerosol samples, we can identify wildfires. We will develop a spatial dataset of the physical and chemical characteristics of the 2025 particulate matter. Further, "background" windblown mineral dust can substantially affect the climate system by providing limiting nutrients (e.g., Fe) to the ocean, contributing to nucleation of clouds, and affecting ice-sheet albedo. These impacts are particularly severe in the Labrador Sea. Because windblown dust acts a passive tracer of wind strength as well as an active tracer of the ocean biogeochemical cycle, it can help elucidate the relationships between wind, deep water formation, and ocean productivity. By comparing the composition and flux of the total particulate matter in the aerosols with the core-top and down-core sediments, we can track changes in total particulate loading and source over the Common Era and investigate drivers of variability.

Analysis Required: We will analyze both aerosol and surface sediment samples taken from the Labrador Sea during Summer 2025. We will analyze 58 samples of PM2.5 (particulates < 2.5 μ) and 20 collocated sediment cores using a handheld XRF, elemental and isotope analysis using ICP-MS, XRD, and statistical methods (e.g., PCA) to differentiate between anthropogenic (industrial pollutants, shipping exhaust, combustion burning) and natural (sea-spray, mineral dust, biomass burning) particulate matter. U-Th isotope analyses will determine a "background" late-Holocene value of particulate loading. Down-core paleo-dust records will trace shifts in atmospheric circulation, such as wind belt position and strength, over the Common Era. The student will be encouraged to pursue self-guided research questions, will learn to oversee an independent research project and will gain transferable skills working in a chemistry laboratory and analyzing large datasets. Lab work will average 30 hours/week, with the remaining time focused on data analysis and literature review.

Prerequisites: General chemistry and lab courses at an undergraduate level, as well as an excitement for oceanography, paleoclimate, and/or aerosol emissions, is required!

Mentors: Aviva Intveld (abi2113@columbia.edu), Gisela Winckler (winckler@ldeo.columbia.edu)

Did Icebergs and Variations in Deep-Ocean Circulation Cause the Most Dramatic and Abrupt Climate Changes in the Past?

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

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

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

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

How Does Vehicle Type and Traffic Volume Impact Ultrafine Particle Emissions on an Urban Highway?

Background: Air quality is a major crisis globally, leading to about 8.1 million premature deaths every year. Major pollutants that contribute to this mortality include fine particulate matter ($PM_{2.5}$), ultrafine particles ($PM_{0.1}$), ozone (O_3), nitrogen oxides (NO_x), and more. In particular, ultrafine particles are a major new research thrust as their health impacts may be more severe than those of larger size particles. A key aspect of successful air quality management is understanding and attributing sources of pollutants. Traffic is a major source of air pollutants, especially NO_x, $PM_{0.1}$, and $PM_{2.5}$, but pollutant mixes vary significantly by vehicle type (truck, bus, passenger car, SUV, etc.), fuel type (diesel, gasoline), and drive cycle. Other sources of pollution, such as electricity generating units, also contribute to many of the same pollutants. Pollutant types also have differing negative health impacts and outcomes. Therefore, identifying and understanding the contributions of individual sources to pollution levels is a critical piece to reducing pollution exposure.

Analysis Required: This project will take place as part of Lamont's Air Sensors Lab, which works on air pollution and climate monitoring, modeling, and remote sensing. Work will consist of analyzing ~1 year of pollution data from a monitoring supersite located at the Solar One Environmental Education Center near Stuy Town along the FDR expressway in Manhattan. The intern will use computer programming tools (Python) to visualize and analyze air quality data. The intern will also use an unsupervised learning technique called non-negative matrix factorization to attribute sources of air pollution. The instrumentation includes a water-based condensation particle counter (CPC) to measure ultrafine particles ($PM_{0.1}$, particles less than 100 nm in diameter) and a MODULAIR sensor system to measure the particle size distribution as well as mixing ratios from several trace gases. The intern will also conduct several field visits to the monitoring location to conduct a traffic survey to be paired with the pollution data.

Prerequisites: Applicants should have experience in the Python scientific data analysis environment. Interest in air pollution is required, but detailed previous knowledge of the topics is not necessary. Any prior experience in air quality data, statistical modeling, and measurements is a plus. Willingness to travel to the field site (reachable by subway) in lower Manhattan is required. Students majoring in any science or engineering discipline will be competitive candidates.

Mentors: Daniel Westervelt, danielmw@ldeo.columbia.edu, 845-365-8194;

How Well Can We Analyze and Visualize Summertime Pollution Transport?

Background: Recent studies have shown that the summer monsoon system provides an efficient pathway for transporting pollutants from the surface to the stratosphere. Observations from satellites, aircraft, and balloon measurements consistently reveal elevated concentrations of tropospheric pollutants in the upper troposphere and lower stratosphere (UTLS) over the Asian and North American summer monsoon regions. These pollutants can substantially influence stratospheric chemistry and climate and may contribute to the depletion of the stratospheric ozone layer. Consequently, understanding the transport pathways from the surface to the stratosphere, as well as their year-to-year variability, is critically important.

Analysis Required: This project will analyze and visualize the transport of pollutants from the surface to the stratosphere using state-of-the-art chemistry–climate model simulations. By applying tagging diagnostics for regional surface emissions, the project will quantify transport pathways and efficiencies from major source regions, including East Asia, South Asia, North America, and Europe. The analysis will also investigate interannual variability in transport and the associated atmospheric circulation processes that drive it. In addition, the project will develop visualizations of pollutant transport using NCAR's VAPOR visualization platform or similar tools and share the results with the broader public. On average, the intern will spend approximately 30 hours per week conducting computational analyses, with additional time devoted to literature review, writing, and discussions with mentors. Through this work, the intern will develop and strengthen analytical and computational skills, with a particular emphasis on techniques commonly used in climate science.

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

Mentors: Yutian Wu, yutianwu@ldeo.columbia.edu, 845-365-8353

Enhancing Global Urban Air Quality Analysis Using High-Resolution Time-Series Grids of Population Weighted, PM2.5 Data

Background: Air pollution is a major global public health challenge. The World Health Organization (WHO) estimates that 4.2 million people die annually as a result of exposure to outdoor air pollution—more than the global Covid mortality peak during 2021 (approximately 3.4–3.5 million). Much of this is linked to fine particulate matter ($PM_{2.5}$); widely recognized as the most hazardous air pollutant because its small aerodynamic diameter allows it to penetrate deep into the respiratory and cardiovascular systems. Extensive epidemiological evidence shows strong associations between both short-term and long-term exposure to $PM_{2.5}$ and severe cardiovascular outcomes, including stroke, ischemic heart disease, and heart failure. At the same time, global urbanization is accelerating. Currently, 55% of the world's population lives in urban areas, and this share is projected to reach 68% by 2050, with nearly 90% of future urban growth occurring in Asia and Africa. As more people move into dense urban centers—where pollution levels tend to be higher—the number of individuals exposed to harmful $PM_{2.5}$ concentrations will rise. To accurately evaluate human health impacts, it is essential to use population-weighted $PM_{2.5}$ metrics, which adjust pollution measurements according to the uneven geographic distribution of populations across urban landscapes. This approach provides a more realistic estimate of human exposure compared to simple area-based or unweighted concentration averages.

Data, Methodology, and Analysis Required: This study seeks to develop a population-weighted $PM_{2.5}$ exposure dataset for urban areas. Working with mentors and external collaborators, the student will collect and process a range of geospatial data formats, including vector shapefiles and gridded raster datasets, and will support the conversion of global $PM_{2.5}$ products from NetCDF to GeoTIFF formats. The student will focus on one or more selected cities and integrate multiple large-scale datasets, including daily or annual mean $PM_{2.5}$ estimates produced at approximately one-kilometer resolution using machine learning models developed in collaboration with the Harvard School of Public Health, the Global Urban Polygons and Points dataset, and the Gridded Population of the World, Version 4. Using these data, the student will compute population-weighted $PM_{2.5}$ concentrations. The analytical workflow will leverage advanced geospatial data science libraries such as geopandas, rasterio, rioxarray, and xarray. The final deliverables will include population-weighted $PM_{2.5}$ exposure maps for the selected major cities. This project contributes to a broader research effort by establishing a reproducible methodological framework that can be applied to urban settings worldwide to enhance air quality assessment.

Prerequisites: Interest and knowledge in global air quality work. Interest in advanced data science like AI/ML. Basic knowledge and skills in Python and R coding. Geographic Information System (GIS) knowledge will be a plus.

Mentors: Xiaoshi Xing, xing@ciesin.columbia.edu, CIESIN, 845-365-8967; Jung-A Lim, jl6726@columbia.edu, CIESIN