How Much Pollution Do Forests Remove from the Atmosphere?

Background: Mercury (Hg) is a neurotoxic environmental pollutant distributed through the atmosphere to remote ecosystems globally. Atmospheric Hg, emitted from anthropogenic and natural sources, deposits via various dry and wet (e.g., rainfall) deposition processes. One important dry deposition process includes vegetation uptake of gaseous mercury from the atmosphere by plants, which subsequently is transferred to soils (hence deposited) when plants die off or shed leaves. We now understand that this "vegetation pump" dominates as a source to land accounting for 54-94% of soil mercury, but no direct measurements of this process is available from some of the most abundant ecosystems; forests. Trees also take up large, but not well constrained, amounts of ozone (O_3), an atmospheric pollutant that causes respiratory and leaf damage. To estimate the vegetative and soil uptake of O_3 and Hg, we will measure carbon dioxide (CO_2) and carbonyl sulfide (OCS) at a long-term ecological research site (LTER) in western Massachusetts, Harvard Forest. The student will join a team designing a sampling system and installing new instrumentation at the site. They will learn QA/QC techniques for an established eddy flux site and will use the relationships identified at the forest site to interpret previously collected OCS data.

Anticipated Tasks: This project will require two fieldwork trips of 3-4 days to the Harvard Forest Long-term Ecological Research (LTER) site in western Massachusetts to deploy a laser spectrometer. Work before the first trip will be spent at Lamont working in the laboratory preparing instruments for deployment. After deploying the instrument, time will be spent analyzing the incoming data and previously collected data using R software.

Skills required: A lab science class is required. Coding experience in Python, R or MatLab, and/or experience working with different file formats and analyzing data is also an advantage but not essential. Communication skills are highly valued for thoroughly documenting codes and disseminating scientific findings.

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East Antarctic Glacial Landscape Evolution (EAGLE): What Can Thermochronology Tell Us About Connections Between Ice Sheets And Tectonics?

Background: Antarctica is almost entirely covered by ice, in places over two miles thick, and this ice hides a landscape that is one of Earth's last unexplored frontiers and that is not even as well-known as the surface of Mars. Ice-penetrating radar images of this landscape reveal remarkable features including mysterious entombed mountains larger than the European Alps and huge fjords twice as deep as the Grand Canyon. But radar cannot tell us when these features formed. A key to understanding how ice will react to future warming climate and impact sea-level is being able to replicate how such ice reacted to known past warmer climate. To gain this understanding requires an accurate picture of the former landscape over which this ice first formed and flowed. The main objective of this project is to reconstruct a chronology of East Antarctic subglacial landscape evolution to understand the tectonic and climatic forcing behind landscape modification, and how it has influenced past ice sheet inception and dynamics. Our approach focuses on acquiring a record of the cooling and erosion history contained in East Antarctic-derived detrital mineral grains and clasts in offshore sediments deposited both before and after the onset of Antarctic glaciation. Samples will be taken from existing sediment core material from offshore Wilkes Land (100°E-160°E) and the Ross Sea. Multiple geo- and thermo-chronometers will be employed to reconstruct source region cooling history including U-Pb, fission-track, and (U-Th)/He dating of zircon and apatite, and $^{40}Ar/^{39}Ar$ dating of hornblende, mica, and feldspar. This offshore record will be augmented and tested by applying the same methods to onshore bedrock samples in the Transantarctic Mountains obtained from the US Polar Rock Repository and during fieldwork conducted in November 2017.

Analysis required: This project will require some rock identification and description of samples collected from the TransAntarctic Mountains and from offshore Antarctica. Where appropriate, samples will be dated with 40Ar/39Ar geochronology, and some will be used for training and in thermochronology (at a two-week workshop at University of Arizona)

Prerequisites: some knowledge of rocks and an interest in geochronology and Antarctica

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How Does Drought Affect U.S. Air Pollution?

Background: It is well known that air pollution levels are strongly correlated with temperature across much of the U.S.A., with a significant relationship emerging for atmospheric humidity in the Southeastern U.S.A. It is far less understood how air pollution varies with drought, although recent work indicates possible connections between biogenic precursor emissions (e.g., emissions from vegetation that are often sensitive to temperature and moisture) to ozone and fine particulate matter, the two top pollutants (in terms of population exposure) regulated under the U.S. National Ambient Air Quality Standards (NAAQS). Newly available multi-decadal records of chemical composition retrieved from satellite instruments offer an exciting opportunity to explore changes in air pollutants and in particular their precursor emissions by compositing over drought and non-drought conditions.

Anticipated tasks: The undergraduate intern will begin by focusing on a single U.S. region, guided by the literature which we will review together at the beginning of the internship. The intern will analyze a few different datasets to identify signals that emerge during drought and non-drought conditions for this region. Specifically, the intern will use at least one drought index to identify when and where droughts occur over the region, and then use that index to composite air pollution datasets into drought vs. non-drought periods. The air pollution datasets include ground-based in situ measurements from U.S. air quality networks with which our group routinely works, as well as multi-decadal satellite records of air pollutant precursor gases, with which our group has experience. Based on recent studies, the intern may also composite these air pollution datasets based on time since beginning of drought to determine if in some cases length of drought affects the sign of the air pollution response. We will screen for other meteorological variables that may be confounded with a drought response; for example, we will search for similar temperature ranges in drought versus non-drought conditions to remove the effect of temperature alone on air pollution.

Skills required: A lab science class is required. Coding experience in Python, R or Matlab, and/or experience working with different file formats and analyzing data is also an advantage but not essential. Communication skills are highly valued for thoroughly documenting codes and disseminating scientific findings.

Mentor: Arlene Fiore: amfiore@ldeo.columbia.edu, (845) 365-8580

What is the Role of Microplastics in the Aquatic Environment and Their Impact on Marine Organisms?

Background: Plastic pollution is now recognized as one of the most significant threats confronting our rivers and global oceans. One of the single most important shortcomings of plastics is that they do not degrade easily and can persist in the aquatic environment for months, years and even decades, eventually making their way into the food chain in the form of small microplastic particles. While it is well known that many marine zooplankton, fish and even shellfish ingest marine microplastics, there is very little known as to how microplastics impact the physiology and growth rates of marine animals. As part of the intern program, students will have the opportunity to participate in field studies to study the types of microplastics found in the waterways around New York City, characterize these particles and investigate their impacts on the feeding and growth rates of marine organisms. Results from this study will be used to test the following hypotheses:

- H_1 - Biological interactions with plastics predominantly occur in regions of high productivity and close to sources of microplastic pollutants, such as near waste water treatment plants.
- H_2 - Marine microplastics are actively consumed and cycled by a variety of marine organisms, including pelagic mesozooplankton and mesopelagic fish. These organisms facilitate the sequestration of plastic to deeper waters and marine sediments.

Prerequisites: College-level, lab-based biology and/or chemistry class.

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What Controls the Ocean Heat Transport?

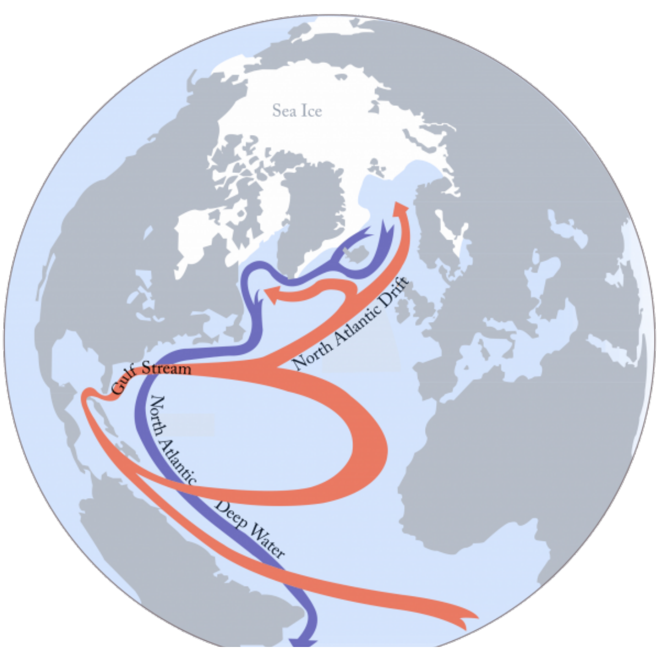
Background: The large scale flow in the Atlantic Ocean can be divided into two components: the meridional overturning circulation and the gyres. The meridional overturning circulation is northward in the top 1000m of the Atlantic Ocean and southward at depth (see figure). The gyres are horizontal circulations driven by local wind. Both the gyres and the meridional overturning circulation contribute to northward oceanic heat transport, which is as important as the atmospheric heat transport in some locations. In the future, melting ice on Greenland may cause a slowdown of the meridional overturning circulation. This project uses a new diagnostic and an ocean model to assess how the heat transport by the gyres is related to heat transport by the overturning circulation on intra-annual to decadal timescales.

Analysis Required: A new diagnostic, proposed by Cessi and Jones (2018), will be coded in python and applied to time-averaged output from a data-assimilating global ocean model, which will be run ahead of time. This will involve:

- Characterizing the time-averaged flow field in a realistic global ocean model by creating a pseudo-streamfunction of the flow above a mid-depth isopycnal
- Identifying which parts of the pseudostreamfunction comprise the northward flowing overturning circulation and which parts comprise the gyres
- Plotting the heat transport in each part of the flow as a function of latitude
- Repeating the above steps on monthly time scales and comparing the results to existing literature. The goal is to better understand the partition of heat transport between the overturning and the gyres.

Prerequisites: You should have taken Calculus III (multivariable calculus) and General Physics 1 or equivalent. Some python knowledge would be helpful.

Mentors: Spencer Jones: spencerj@ldeo.columbia.edu, 646-706-6591 with support from Ryan Abernathey



The red line represents the flow in the upper ocean, which is comprised of a recirculating gyre and the upper limb of the Atlantic meridional overturning circulation, which is northward. The blue line represents the lower limb of the Atlantic meridional overturning circulation (below 1000m), which is southward. Image by Rahmstorf (1997).

Why is the Organic Carbon so Young in Pleistocene Wells in Bangladesh?

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 low arsenic contents. This source of low arsenic water is fortuitous and provides a clean drinking water source. Because these deeper wells are more expensive, the Bangladesh government and NGOs usually install them for use by multiple households. At the same time the country is rapidly developing. Dhaka, the capital continually withdraws more water from the deep aquifers. In addition, water use is also increasing in rural areas with more use of the Pleistocene aquifers. It was usually assumed that the deep aquifers would remain low in arsenic however we are now finding some wells with elevated arsenic. In addition, radiocarbon analysis indicates that dissolved organic carbon is entering these deep aquifers with ages 1000's of years younger than the dissolved inorganic carbon. The goal of this work is to better constrain the carbon source utilized by the microbes in order to understand the potential for arsenic release. Analysis of RNA has the potential to help us understand arsenic and carbon dynamics in these newly contaminated aquifers. We have collected filters from deep wells in Bangladesh. 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.

Mentor: Brian J. Mailloux bmaillou@barnard.edu 212-854-7956

Figure 1. Field Site in Bangladesh. This is an 800 foot deep well that is low in arsenic. However the radiocarbon dates of the dissolved organic carbon are significantly younger than the dissolved inorganic carbon indicating intrusion of young, reactive groundwater. .

'Cool' or 'Hot'? What are the Crystallization Temperatures of Early Arc Magmas?

Background: Arc magmas erupt from arc volcanoes which are strung along convergent plate margins, where cool, volatile-rich oceanic lithospheric plates (or 'slabs') are drawn – or 'subducted' – beneath another lithospheric plate with either oceanic or continental crust. The subducting slab releases hydrous components into the overlying mantle wedge, where it triggers partial melting to produce volatile-rich and viscous arc magmas. It has been shown that the composition of arc magmas is distinct from those of magmas erupting along the submarine mid-ocean ridges or in intraplate settings (e.g. Hawaii) and that this difference is related to the integration of material from the subducting slab. But does the involvement of the components recycled from the cool subducting slab also affect physical variables, such as the temperatures of melt formation? In this project, we collect data on the crystallization temperatures of early arc magmas using a geothermometer based on the major and trace element composition of olivine phenocrysts and its tiny inclusions of chromian spinel. Olivine and chromian spinels are the earliest crystallizing minerals in primitive arc magmas and thus allow insights into the temperatures of melt formation in the mantle. Samples to be investigated are from the Kurile arc which is constructed on oceanic crust, and the New Zealand arc which is constructed on continental crust.

Analysis Required: This is a laboratory project. The student will prepare mineral mounts of olivines and included Cr-spinels and analyze them by electron microprobe and laser- ICPMS methods. Evaluation includes data reduction, data management in a relational database and visualization. Work will require ~25 hrs/wk.

Prerequisites: None, although basic knowledge of the solid Earth geochemical cycle is a plus. The student will be required to take courses in laboratory and fire safety training.

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How Well Can Environmental Tracers Track Ground-water Contamination from Hydrofracking and Carbon Sequestration?

Background: Energy production and water resources are linked on many levels. For example, unconventional gas production by hydraulic fracturing and subsurface CO_2 sequestration may leak gases such as CO_2 and CH_4 (and higher hydrocarbons) and various contaminants such a lithium, bromide, radium etc. into the local drinking water aquifers. These sites tend to be surrounded by rural settlements and small towns that rely on groundwater as primary source of water. The goal of the project is to develop tools that can act as early warning signs of the arrival of pollutants. Different contaminants migrate at different speeds in the subsurface, and gases might move faster than the groundwater itself. We are trying to identify the contaminants and also tracers that are added to the fracking fluids or the CO_2 that move the fastest. The detection of these substances would clearly identify contamination sources and serve as a warning that worse is to come later. The tracers we plan to use include perfluorocarbons, SF_6 and SF_5CF_3. Most of the work will be focused on laboratory experiments, but we might try a small-scale field test of applications as well. The lab experiments involve a core flooding device that allows us to pass fluids with and without tracers and contaminants through an aquifer rock cylinder and which allows sample collection on the outflow side.
Anticipated tasks: The undergraduate intern will work in the laboratory at Lamont primarily with gas chromatographs and our core-flooding device. Some measurements will be performed with an ion chromatograph and an ICPMS (Inductively coupled plasma mass spectrometer). We plan to apply this technique in a short-term field experiment as well.
Skills required: A lab science class is required, ideally in chemistry.
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