How Does the Potent Greenhouse Gas Methane Produced in Landfills Reach the Atmosphere?

Background: Methane is a potent greenhouse gas, thirty times more potent than CO_2. Therefore, constraining methane sources can contribute to predictions of how our climate will change over time. Landfills are one of the largest sources of methane across the US, New York state and, surprisingly, New York City. Methane is produced in landfills through the microbial decomposition of biological waste. Studies have indicated that the active face of the landfill is the location of most of the methane emissions. The Freshkills Landfill in Staten Island was recently closed and the active face of the landfill was covered over in November 2021. Before the face was closed, we measured larger than expected methane emissions into the atmosphere from the landfill and found that the dominant source of methane was not from the active face, but from the leachate pumps as they send waste water to the waste water treatment plant before discharge.

Work Required: This project will collect water and air samples from around landfills in the New York city area and quantify the methane concentration and biological (BOD) and chemical oxygen demand (COD) in the samples. The fieldwork includes in field sampling at a site at various temperatures and after rain events. The Lab work includes measuring the methane and higher hydrocarbons in the samples with a gas chromatograph with a flame ionization detector (GC-FID) and calculating BOD/COD from oxygen measurements over time in sealed samples using a fluorescence oxygen probe. The concentration data will allow us to quantify the methane fluxes from the landfill and propose solutions to the landfill managers to mitigate these emissions. Field and Lab work will average 30 hrs. /wk., with the rest of the time being focused on data analysis, literature review, etc.

Pre-requisites: General chemistry and lab courses are required; Organic or analytical chemistry with interests in biological and environmental issues would be a plus.

Mentors:

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What Is the Timing of Mineralizing Fluid Flow in the Paradox Basin?

Background: The Paradox Basin is associated with the Ancestral Rocky Mountains in the southwestern United States. The late Paleozoic basin preserves multiple generations of deposition, fluid flow, and sediment deformation, and contains economically-important fluid-associated enrichments of minerals such as copper, vanadium, and uranium. The ore-forming fluids are associated with bleaching of red bed sandstones such as the Navajo Sandstone, a Lower Jurassic cross-bedded unit separated from overlying units by the J-2 Unconformity, a widespread erosional surface in the western US. In many places the Navajo Sandstone is bleached by fluid interaction and contains iron-oxide-rich pipes that appear hydrothermal in nature. These pipes and the clues they provide about paleofluids are the targets of this summer research project, the main goal of which will be to measure (U–Th)/Ne ages of hematite in the pipes and to interpret the ages in the context of the fluid flow history of the Paradox Basin.

Rocks rich in hematite can be dated using geochronometers that rely on the decay of uranium present in concentrations from hundreds of ppb to tens of ppm in this mineral. The U-Pb systematics are unfavorable due to substantial non-radiogenic lead, so chronometers involving the decay of U to noble gas daughters are more useful. The (U–Th)/He system is most common, but it has a relatively low closure temperature, and therefore it often records cooling ages rather than the age of rock formation. By contrast, hematite is quite retentive for Ne, and so the (U–Th)/Ne system can be used in hematite to date rocks that have experienced significant reheating (typical closure temperature is at least 250°C). The iron oxide-rich hydrothermal pipes in the Navajo Sandstone have been dated to 30-35 Ma by (U–Th)/He, which likely represents a cooling age due to post-Jurassic burial by several km of Cretaceous sediments. The Paradox Basin contains both abundant oil and gas reserves, suggesting heating of 100-200°C. The geothermal gradient is ~ 20-30°C in this part of the Ancestral Rockies, and estimates for maximum burial depth of the older rocks in the basin are <10 km, so the (U–Th)/Ne system is probably not reset. The (U–Th)/Ne ages of the hematite in the hydrothermal pipes in the Navajo Sandstone are expected to reflect the age of the economically-important fluid flow that bleached its top.

Work Required: The student will prepare samples for analysis, design and conduct neon measurements on the Thermo Helix MC in the noble gas lab, and subsequently prepare samples for U and Th analysis by collaborator Pete Reiners at the University of Arizona. The first half of the project will require full 5-6 hour days in the lab, but the second month will have more flexibility as analyses will be fully automated once they are set up. The student will also have the opportunity to join a field trip in late May to collect samples with the team from the University of Arizona. This is one part of an expansive collaboration, and the student will have the opportunity to continue working on this project during the subsequent 2022-2023 school year.

Prerequisites: The skills required of the student will include basic rock and mineral identification, laboratory skills, and ideally noble gas mass spectrometry experience.

Mentors: Stephen Cox, cox@ldeo.columbia.edu, 845-365-8537
University of Arizona collaborator: Pete Reiners, reiners@arizona.edu

Are the Anomalous Behaviors During 2015-2017 of the Tropical Indonesian Throughflow and of the Southern Ocean Weddell Sea Bottom Water Characteristics Related?

Background: A prime example of interocean exchange is the Indonesian Throughflow (ITF) of warm tropical Pacific water into the Indian Ocean. A prime example of deep ocean ventilation is the production of cold Antarctic Bottom Water (AABW) along margins of Antarctica, which spreads along the sea floor well into the northern hemisphere. A predominant component of AABW is Weddell Sea Bottom Water (WSBW), formed in the western boundary of the Weddell Gyre in the South Atlantic sector of the Southern Ocean. They both are central components of the global ocean and climate systems. A program at Lamont-Doherty has been monitor the Makassar Strait Throughflow (~80% of the ITF) since 2003, and the export of WSBW from the western Weddell Sea since 1999. The Makassar Strait Throughflow relaxed to ~9 Sv (Sv = 106 m3/sec) from the longer term average of 12 to 13 Sv during the strong 2015 El Niño event; during the 2016 into 2017 La Niña reached 'historical' highs, ~20 Sv, mainly due to an anomalous increase in the sub-thermocline (>300 m) transport. The WSBW also revealed significant change during the 2015-2017 period: an anomalous salinity decrease was recorded, induced by injection of low salinity winter open ocean surface water, rather than to changes in the shelf water characteristics. In addition to the change in the WSBW salinity a sea ice free (polynya) region appeared in the Weddell Gyre central area. Both of these changes are likely linked to the spin up of the winds over the Weddell Gyre. Are the changes in the warm ITF and of the cold WSBW 2015-17 related? The research project will explore the teleconnection of ENSO and associated winds over tropical Pacific, to the winds over the Southern Ocean, with focus on the Weddell Gyre.

Work Required: The student will be correlating, with varied time lags, the observational time series of ocean current and temperature/salinity of the export of Weddell Sea Bottom Water from the Weddell Sea, Southern Ocean, with the Indonesian Throughflow carrying tropical Pacific water into the Indian Ocean; the overlap period of these two time series is 2004-2017. Then, they will investigate the phases and correlation of the tropical and southern ocean climate indices time series, mainly nino3.4 and SAMS that affect the atmospheric forcing of the tropical Pacific and southern ocean. In the analysis phase the student is expected to compare the two time series and investigate the connect with the climate indices.

Pre-requisites: Basic statistics, some knowledge of data analysis software, such as Python or MATLAB.

Mentor: Arnold Gordon: agordon@ldeo.columbia.edu

How Did the Afro-Eurasian Faunal Exchange Reshape Ecological Niche Partitioning in Mammals?

Background: The ecology of modern Africa began to emerge over 20 million years ago, when the African plate collided with Eurasia. During the ensuing faunal exchange between landmasses, a great diversity of hyraxes found at paleontological sites across northeastern Africa were replaced by numerous Eurasian lineages that we recognize today. While the specific African taxa that lived before and after the exchange are now extinct, we can study their ecologies by examining the stable isotope ratios of their fossilized remains. This is because stable isotopes – variants of common elements found all around us – partition across landscapes and between individual organisms based on ecological patterns. Can isotopes tell us what African ecosystems dominated by hyraxes looked like? And did Eurasian lineages dispersing into Africa replace hyrax niches, or establish wholly new ecosystems?

Work Required: This project will analyze stable carbon and oxygen isotope compositions from fossil hyrax teeth derived from northeastern Africa. The student will compare stable isotope compositions between hyraxes that lived at the newly discovered, pre-exchange paleontological site of Topernawi in the Kenyan Turkana Basin, and stable isotope compositions at multiple sites in the same basin that formed after the exchange. The student will work in the Lamont-Doherty Earth Observatory Organic Geochemistry and Stable Isotope laboratories. There, they will work with the project mentors to learn to prepare fossils for stable isotope compositions, make measurements, and analyze data. The student will read and discuss academic papers, will work with us to develop more specific hypotheses about changing ecological patterns across the Afro-Eurasian faunal exchange, and will test these hypotheses using data they produce.

Pre-requisites: General chemistry and lab experience are required.

Mentors: Daniel Green, dgreen@ldeo.columbia.edu, 845-365-8542;
Kevin Uno, kevin.uno@ldeo.columbia.edu.

What Do Marine Records Tell Us About Former Ice Sheets in Patagonia and Ice Age Climates in the Southern Hemisphere?

Background: Marine records not only document how glaciers and ice sheets changed in Patagonia, but oceanic and atmospheric changes also actively impacted their behavior. Moreover, glaciers tend to erode the landscape each time they expand making their geologic record incomplete, whereas marine sediments can provide continuous records of change but they are distal to glaciers. Hence, studying both types of natural archives – that is, offshore and onshore – can lead to a better understanding of how glaciers in Patagonia varied alongside changes in the nearby Southern Ocean, during Ice Age climates. This project seeks also to answer an overall question, how can we compare the terrestrial and marine records specifically around Patagonia to gain a better understanding of both approaches and what they tell us? We will focus on a new marine core recently obtained in 2019 from IODP Site U1534, from the South Falkland Sediment Drift. The core's sediments provide the first marine archive of Patagonian glaciations over the last few hundred thousand years and longer. The age model for the core, based on its benthic foraminiferal 18-O correlated or tuned to other (global) 18-O records, indicates that while sedimentation was continuous over the last two glacial-interglacial cycles (~200,000 years), prior glacial intervals are poorly represented.

Work Required: The student will perform census counts to quantify how the major components (detrital, authigenic and biogenic) of the coarse sediment fraction (>125 micron) in U1534 vary over the last two recent glacial-interglacial cycles. To better interpret earlier glacial intervals (for example, Marine Isotope Stages 8, 10 and 12) where sedimentation was intermittent, the student will characterize sediment components relative to X-ray fluorescence (XRF) data and climate cycles. In addition, gypsum appears to have formed during periods of hiatus in sedimentation. The student will study and pick gypsum crystals for Strontium isotope analyses, which may validate the marine core's existing age model, and provide ages for intervals barren of benthic foraminifera. Understanding how sedimentation varied and sediment processes during the last two glacial cycles and earlier glaciations will provide new insights into the history of the Patagonian Ice Sheet and how it varied alongside the ocean's behavior during Ice Age climate changes.

Skills Required: Lab work required including substantial microscope time and attention to detail.

Pre-requisites: None required, but comfort with Excel, or other data-oriented programs are a plus.

Mentors: Mike Kaplan, mkaplan@ldeo.columbia.edu
Sidney Hemming, sidney@ldeo.columbia.edu
Collaborator Victoria Peck from the British Antarctic Survey, vlp@bas.ac.uk

Boom! Splash! What Can We Learn About Geysers (And Volcanoes) From Building a Big One in the Lab?

Background: With over 4 million annual visitors to Yellowstone's Old Faithful geyser, public fascination with geysers is undeniable. Yet, the scientific understanding of geysers is incomplete. While it has been understood for over a century that geyser eruptions are caused by the sudden boiling of water in underground conduits, we do not understand what triggers these boiling events, and how the size and shape of the underground conduits affect a geyser's behavior. Recent studies at geyser fields in Yellowstone National Park, El Tatio on the Chilean altiplano, and the Geyser Valley in Kamchatka, have shown that the underground plumbing systems at these sites include a reservoir that is offset to the side relative to the main eruption conduit. In such systems, steam gets captured in the side reservoir, earning it the name 'bubble trap'. The discovery of this geometry is the most significant advance in several decades, but we are only beginning to understand how it affects a geyser's behavior.

Work Required: For this project, we will create an analogue geyser setup in the Fluid Mechanics laboratory at LDEO. The setup will include a bubble trap, an advancement over previous experimental works. Our team will run a series of experiments to study how fluids behave in this type of system. The results from the experiments will then be compared and combined with mathematical models (being developed by undergraduate students at UC Davis) to relate behaviors observed in the lab to the much larger systems that we encounter in nature. The project will provide hands-on research experiences for undergraduate students, including experience in experiment planning, lab safety protocols and procedures, data collection, analysis, visualization, and interpretation. Students will take part in turning the work into instructional materials for educators through videos and reports. The laboratory geyser will be exhibited at the Lamont Doherty Earth Observatory open house, visited by thousands of people each year, and the students are welcome to take part in this exciting event as well.

Pre-requisites: organization, some mechanical/electrical engineering abilities, ability to climb a tall step ladder.

Mentor: Einat Lev, einatlev@ldeo.columbia.edu 617-794-0660

What Are the Impacts of Extreme Episodic Events on the Health and Ecology of the Long Island Sound Ecosystem and How Do These Influence Vulnerable Coastal Communities?

Background: This is an opportunity for an undergraduate student to participate in exciting field research that examines how human activities, seasonal processes, and episodic events impact the water quality and ecology of Long Island Sound. Like many similar highly populated estuaries, the Long Island Sound suffers from water quality problems, including hypoxia, anoxia, eutrophication, and recurrent harmful algal blooms (HABs). Within the past twenty-five years, harmful algal blooms have devastated New York coastal waters, disrupting food chains for many marine species and impacting economically viable fisheries, aquaculture, and recreation activities. These environmental hazards are expected to intensify as the Sound is becoming increasingly vulnerable to climate change. This project aims to quantify how human activities and episodic events impact seasonal and spatial transitions in phytoplankton assemblages across Long Island Sound, and how these transitions are linked to changes in the amount and quality of nutrients and dissolved organic matter entering the system. We also aim to understand impacts on coastal communities, especially low-income communities who appear to be disproportionately impacted by eutrophication hypoxia and harmful algal blooms. The project integrates satellite observations of both the terrestrial and aquatic domains with multi-disciplinary ecological and paleo-ecological datasets, demographic information, hydrodynamic-biogeochemical ecosystem models, and socioeconomic/population dynamics models.

Work Required: The student will build skills in diverse field and laboratory techniques, data analysis and the use of analytical instruments. Water samples collected from rivers, coastal marshes, and the Sound's estuarine waters will be characterized chemically and optically. In-situ measurements of water physicochemical and bio-optical properties will be collected during one-day cruises to study estuarine biogeochemical and ecological processes. The student will collect and process samples, analyze data, and generate quantitative analyses of how natural and anthropogenic disturbances affect water quality and ecological processes in Long Island Sound. Additionally, the student will develop skills in critical analysis, problem solving and scientific communication, and will have the opportunity to link results from this work to projects within the tri-state area aiming at assessing coastal ecosystem vulnerability to climate change. Results from this work may lead to important insights for long-term water quality management and improvement, with important benefits for vulnerable populations.

Pre-requisites: We are looking for highly motivated undergraduate students with strong background and interest in environmental sciences, quantitative skills, and willingness to be part of an interdisciplinary team effort. Experience in programming, field data collection methods, and/or remote-sensing data analysis preferred, but not required.

Mentors: Maria Tzortziou: mt3123@columbia.edu (240-475-5773)
Joaquim Goes: jig@ldeo.columbia.edu (845-365-8467)
Helga Gomes: helga@ldeo.columbia.edu (845-365-8467).

What Are the Major Sources of Nanoplastics in New York City Waterways?

Background: Numerous studies have demonstrated that our environments including our homes are inundated by plastic wastes. They can be physically broken into microplastics (5 mm – 1µm) and nanoplastics (1 µm to 10 nm); The smallest nanoplastics are small enough to be taken up into human tissues and to pass directly into the brain. However, little is known about the impact of these nanoplastics on human health, mainly due to a lack of scientific techniques for identifying nanoplastics. A recent development in Raman Microscopy at Columbia University is game-changing due to an orders of magnitude increase in sensitivity and imaging speed. This new technique provides an ideal tool for identifying nanoplastics because of Raman's ability to fingerprint the signals from plastic polymers. The overall goal of this study is to investigate the size distribution and possible sources of nanoparticles, especially nanoplastics in water and air samples.

Work Required: This project will analyze the abundances and types of nanoplastics in water samples collected from New York City waterways and air samples collected in New York City apartments. Lab work includes isolating nanoplastics from other particles, characterizing nanoplastics using several optical approaches including Raman and the scanning electron microscope (SEM). Lab work will require an average of 30 hrs/wk, with the rest of the time being focused on data analysis, literature review, etc. We also plan to arrange a field trip to New York City to collect air samples.

Pre-requisites: General chemistry and lab courses are required. Organic or analytical chemistry with interests in biological and environmental issues would be a plus.

Mentors:
Beizhan Yan: yanbz@ldeo.columbia.edu, 845-248-1526;
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What Are the Major Pathways by Which Humans Are Exposed to Nanoplastics?

Background: As of 2015, about 6300 million metric tons of plastic waste had been generated worldwide. Physical weathering and photodegradation can break those plastic wastes into microplastics (5 mm to 1 μm) and nanoplastics (from 1 μm to 1 nm). Numerous studies have demonstrated the occurrence and adverse effects of microplastics in our living environment. However, knowledge about nanoplastics is limited mainly due to a lack of scientific techniques to identify these nanoparticles. These nanoparticles are health-relevant because they are small enough to be taken up into human tissues and to directly pass into the brain. A recent development in Raman Microscopy at Columbia University provides an ideal approach to identifying nanoplastics because of Raman's unambiguous fingerprinting of the signals from plastic polymers. The overall goal of this study is to investigate the major exposure pathways of nanoplastics, including ingestion from drinks and inhalation from the air.

Work Required: This project will analyze the abundance and type of nanoplastics in popular drinks and water and air samples collected in New York City. Lab work includes isolating nanoplastics from other particles, and characterizing nanoplastics using several optical approaches including Raman and the scanning electron microscope (SEM). Lab work will require average 30 hrs./wk., with the rest of the time being focused on data analysis, literature review, etc. We also plan to arrange a field trip to New York City to collect air samples.

Pre-requisites: General chemistry and lab courses are required. Organic or analytical chemistry with interests in biological and environmental issues would be a plus.

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How Much Does Upper Ocean Heat Content Contribute to Seasonal Sea Ice Predictability in the Antarctic?

Background: Sea ice in the polar ocean is an active component of the global climate system and amplifies climate change in polar regions. With its large seasonal and interannual variability, Antarctic sea ice greatly affects surface energy balances in the atmosphere and ocean by changing surface albedo, salt injection, and insolation between air-sea interface. Therefore, long-range forecasts of Antarctic sea ice are very much in demand, not only because of the potential importance of sea ice in the global climate, but also for the practical purpose of exploring the Antarctic continent. Unfortunately, such forecasts have not yet matured with any state-of-the-art general circulation models (GCMs) because the complex air–sea–ice interaction processes are still not well understood and are by no means well simulated by these models. Statistical modeling provides alternative approaches. Chen and Yuan (2004) used 20-years of satellite observed sea ice concentration data and reanalysis of atmospheric variables to develop a linear Markov model for predicting Antarctic sea ice for seasons in advance with some skill. Currently, the model is severely outdated. Now, satellite observations have accumulated for 40+ years, providing more information for developing robust statistical models. Moreover, recent studies suggested that the upper oceanic heat content strongly influences sea ice variability at different timescales (Meehl et al. 2019, Lenetski et al., 2021). The long memory of oceanic heat content potentially improves sea ice predictability in statistical models, but has not been incorporated into a Markov model. Our goal is to re-develop the Markov model with updated time series of sea ice and atmospheric variables and additional ocean heat content as a predictor. Through model redevelopment, we will quantify the contribution of upper ocean heat content to sea ice predictability at seasonal timescales.

Work Required: The project will update sea ice concentration, atmospheric pressure, winds, air temperatures, and sea surface temperatures, and upper oceanic heat content data for the period of 1979 to 2020 from public domains. We will modify current model codes to include the longer time series and additional variables. We will carry out cross-validation model experiments to assess the model skill as a function of the number of predictors and to determine the optimal model dimension. The model performance will be evaluated, and the contribution of the ocean heat content will be isolated. We anticipate that a student with computer skills can complete the above tasks under our supervision within 8 weeks.

Pre-requisites: Experience with the computer language Python is required. Basic statistics and probability courses are preferred.

Mentor: Xiaojun Yuan, xyuan@ldeo.columbia.edu, 845-365-8820

References: [1] Chen, D. and X. Yuan, 2004. A Markov model for seasonal forecast of Antarctic sea ice. *Journal of Climate*, **17**(16): 3156-3168. [2] Meehl, G. et al. 2019: Sustained Ocean Changes contributed to sudden Antarctic sea ice retreat in later 2016. Nature Comm. 10 (14). [3] Lenetski et al., 2021. Subseasonal Predictability of Arctic Ocean Sea Ice Conditions: Bering Strait and Ekman-Driven Ocean Heat Transport. *J. Climate*. DOI: https://doi.org/10.1175/JCLI-D-20-0544.1