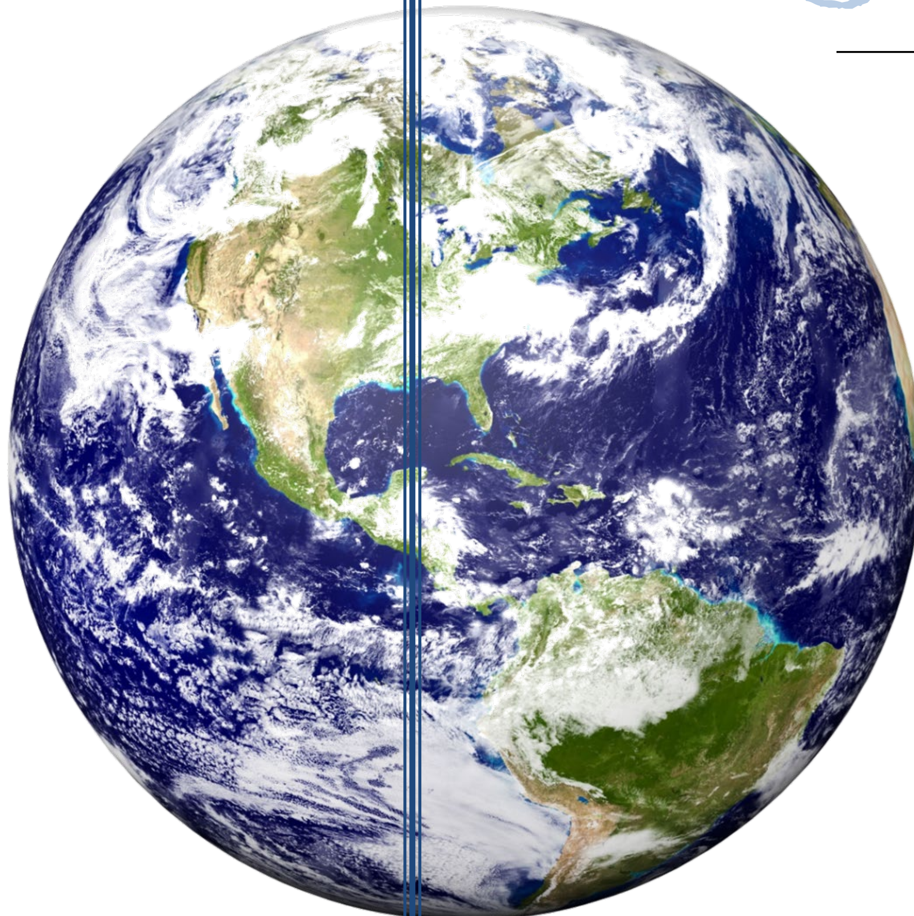


EARTH & PLANETARY SCIENCES

AT HARVARD UNIVERSITY

2019 Senior Thesis Presentations

Thomas Andrew Lee

Molly Michael Wieringa

Margaret Powell

Rebecca Cleveland Stout

Maya V. Chung

Tuesday, May 7th, 2019 11:30 am-1:30 pm
Haller Hall, Geological Museum 102

Please join us for an Undergraduate End-of-Year Reception beginning at 1:30 pm in the Student Lounge (4th Floor, Hoffman Labs).

Please join us for a reception honoring
all of our EPS Undergraduates
1:30 pm
Student Lounge
4^{th} Floor, Hoffman Labs

Thank you for your support!

WELCOME

Message from the Head Tutor and Preceptors:

Thank you for joining us as we celebrate the accomplishments of our senior thesis writers who spent much of their senior year tackling an exciting range of scientific problems. The senior thesis provides an opportunity for students to gain first hand experience in the full scope of research, from in-depth background study, to identification of core questions, design of a research plan, collection and analysis of data, and formation of rigorous conclusions. This year's theses examine methane emission from permafrost in Alaska, use of temperature and salinity to provide a proxy for ocean warming, changes in seasonal rainfall in equatorial Africa, reconstruction of sea-level change using coral reefs, and magma plumbing system associated with the 2018 Hawai`i eruption. Their efforts would not be possible without the support of faculty advisors, graduate students, post docs, and fellow undergraduate students. We thank these mentors and friends and congratulate our seniors on their achievement.

Miaki Ishi
Head Tutor

Esther James and Annika Quick
EPS Preceptors

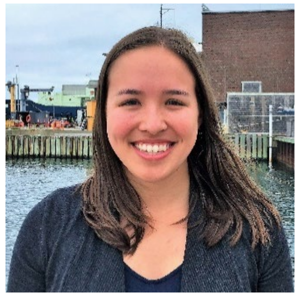
Jim Anderson, Roger Fu, Miaki Ishii, Zhiming Kuang
Undergraduate Curriculum Committee

Chenoweth Moffatt
Academic Program Manager

Maya V. Chung

Concentration: Earth and Planetary Sciences

Quantifying Isopycnal Heave Using Dynamic Depth Warping



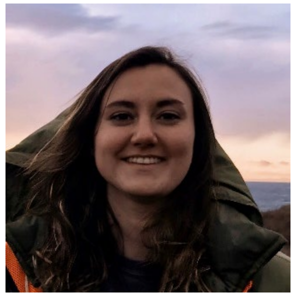
Advisor: **Peter Huybers,** Professor of Earth and Planetary Sciences and Environmental Science and Engineering, Harvard University

Ocean warming has accelerated in recent decades, with concerning implications for sea level rise, large-scale weather patterns, and ocean acidification. A useful quantity for measuring warming trends in an ocean rich with natural variability is heave, or the vertical movement of surfaces of constant density. Heave is influenced by both trends associated with ocean heat uptake and natural changes in ocean circulation, therefore providing insight into how these processes interact. Conventional methods for measuring heave rely on density, which can mischaracterize heave by masking changes in temperature and salinity. This work presents a novel method for measuring heave that combines independent temperature and salinity measurements. This new method outperforms conventional density-based methods for calculating heave. After demonstrating the efficacy of this method across independent datasets near Hawaii, heave is calculated in the North Pacific Ocean and partitioned into contributions from climatic trends and natural variability. Significant warming trends dominate in the high-latitude North Pacific, whereas natural variability due to the seasonal cycle and El Niño dominates in the Equatorial regions. Future work will extend this analysis to quantify heat uptake and naturally-occurring wave processes in the global ocean.

Rebecca Cleveland Stout

Concentration: Earth and Planetary Sciences

Leveraging preservation bias in Last Interglacial coral sea-level records to refine global ice volumes over the ice age



Advisors: **Peter Huybers,** Professor of Earth and Planetary Sciences and Environmental Science and Engineering, Harvard University
Jerry X. Mitrovica, Frank B. Baird, Jr. Professor of Science, Earth and Planetary Sciences Department, Harvard University

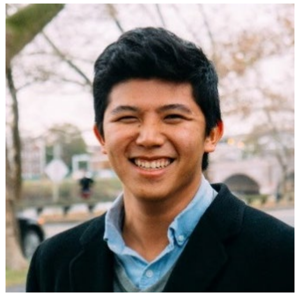
Estimates of sea level during the Last Interglacial (LIG, ~125,000 years ago) underpin our understanding of ice sheet response to warming. Fossil coral reefs provide robust indications of past sea level, but are subject to preservation biases, which have implications for sea level reconstructions and have yet to be explicitly accounted for.

We explore these biases by modeling coral growth and erosion over the last glacial cycle. The model is forced with 900 possible LIG sea level histories, which account for spatial heterogeneity in sea level change produced by Earth's gravitational, rotational, and mantle responses to ice melt. The model generates modern coral fossil elevations, which are compared to observed LIG coral records. Only a subset of sea level histories yield coral elevations consistent with the fossil observations; these consistent histories potentially constrain past sea level. We also identify spatiotemporal changes in the relationship between corals and sea level, which could produce systematic underestimation of sea level at sites that experienced rapid sea level rise (e.g., northern Bahamas). At these sites, across our runs, there is ~40% chance of underestimating sea level by >1 meter. This could have significant implications for LIG reconstructions, estimates of Earth structure, and past and future Antarctic ice sheet stability.

Thomas Andrew Lee

Concentration: Earth and Planetary Sciences

Detection of a "Silent" Magma Intrusion Using Ambient Seismic Noise Autocorrelation Functions from the 2018 Kīlauea, Hawai`i Eruption

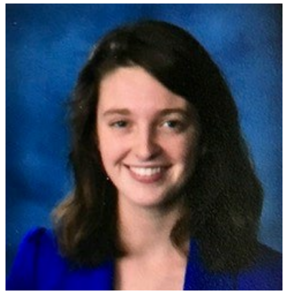


Advisors: **Miaki Ishii**, Professor of Earth and Planetary Sciences and Head Tutor, Earth and Planetary Sciences Department, Harvard University
Paul Okubo, Research Geophysicist – Seismology, Hawaiian Volcano Observatory, United States Geological Survey University

Volcanic eruptions are among the most unpredictable and devastating of natural hazards, and a long-standing goal of volcano monitoring has been identification and understanding of signals associated with the movement of magma leading up to eruptive events. Recent focus has been given to the technique of analyzing ambient seismic noise (non-earthquake derived ground shaking, for example, that from ocean waves) to gain information about the structure beneath the ground and its evolution. In this senior thesis, this technique is applied to Kīlauea volcano in Hawai`i during the eruptive activity of 2018. A loss of coherence (decorrelation) in the ambient seismic noise correlation functions is observed progressing across the volcano from the summit to the area of eruptive activity over the course of about a week. The progressive decorrelation signal is attributed to microearthquakes and subsurface fractures. This result, combined with other ground observations, suggest a magmatic intrusion, albeit with no related earthquakes. Currently, volcano-monitoring techniques rely upon earthquakes caused by a magmatic intrusion to identify it. A "silent" intrusion, as proposed by this study, would have the ability to potentially produce an unwarned-of-eruption. This has wide-reaching implications for volcano monitoring and the ability to protect lives and infrastructure.

Molly Wieringa

Concentration: Earth and Planetary Sciences



Changing Rains Down in Africa: Verifying Shifts in the Position of the Intertropical Convergence Zone Using a New Seasonal Rainfall Model

Advisor: **Peter Huybers,** Professor of Earth and Planetary Sciences and Environmental Science and Engineering, Harvard University
Angela Rigden, Post-Doctoral Scholar, Earth and Planetary Sciences, Harvard University

Growing concern surrounding food security in various regions of equatorial Africa has motivated recent efforts to better understand the seasonal precipitation cycle on the continent. Global climate models predict shifts in large-scale drivers of precipitation as a response to anthropogenic climate change; the Intertropical Convergence Zone (ITCZ), a global climate phenomenon connected to equatorial rainfall, is perhaps the most prominent example. While many studies have noted real and present changes in regional seasonal cycles, few have investigated whether such changes might be forced by predicted shifts in large-scale systems. But why should seasonal precipitation be influenced by regional drivers alone? Can evidence for the theorized shifts in the ITCZ be found in the observational rainfall record?

To answer these questions, we propose a novel mixed Gaussian model for seasonal precipitation which isolates metrics for seasonal timing, magnitude, and duration from observational rainfall data. Using these metrics, we track change in seasonal behavior of precipitation over the last century. Trends in seasonal timing across equatorial Africa reinforce the theory of a shifting ITCZ and imply that such a shift has already been initiated. This result underscores the importance of considering both global and regional influences while trying to understand precipitation behavior on any scale. Additionally, changes in seasonal timing will also have very real consequences on agriculture in the region, as the success of rain-fed subsistence crops that feed most of the population depends upon proper timing of planting. As such, understanding changes related to seasonal rainfall may better inform future agricultural practices.

Margaret Powell

Concentration: Earth and Planetary Sciences

Four Years of Alaskan Methane Emissions from the Carbon in the Arctic Reservoirs Vulnerability Experiment (CARVE) Aircraft Campaign Show Substantial Late Season Contributions

Advisor: **Steven C. Wofsy**, Abbott Lawrence Rotch Professor of Atmospheric and Environmental Science, Earth and Planetary Sciences Department, Harvard University

Amplified arctic warming puts a large pool of permafrost soil carbon at risk of being mobilized into greenhouse gases including methane. Global atmospheric methane concentrations have been increasing rapidly and there are concerns that this change may be driven by increased emissions from the warming arctic. Measuring the current methane balance of the arctic permafrost region is critical for assessing predictions of future emissions. I used aircraft data to quantify methane emissions at a regional scale for April-November, 2012-2015 and examined emission sensitivity to large interannual climatic variability. I found that net growing season contributions and mean monthly emissions from the region did not vary significantly between 2012 and 2015.

Earlier studies from the Wofsy research group highlighted the importance of late season methane emissions, which were previously thought to negligible. Late seasons emissions occur because a layer of soil at depth can remain thawed and therefore biologically active for months after surface soils have frozen. I determined estimates of monthly methane emissions April-November from three ecoregions (North Slope tundra, Southwestern tundra and boreal). October and November methane fluxes were substantial from all three ecoregions. Late season emissions appear to have the potential to significantly change the arctic methane budget.