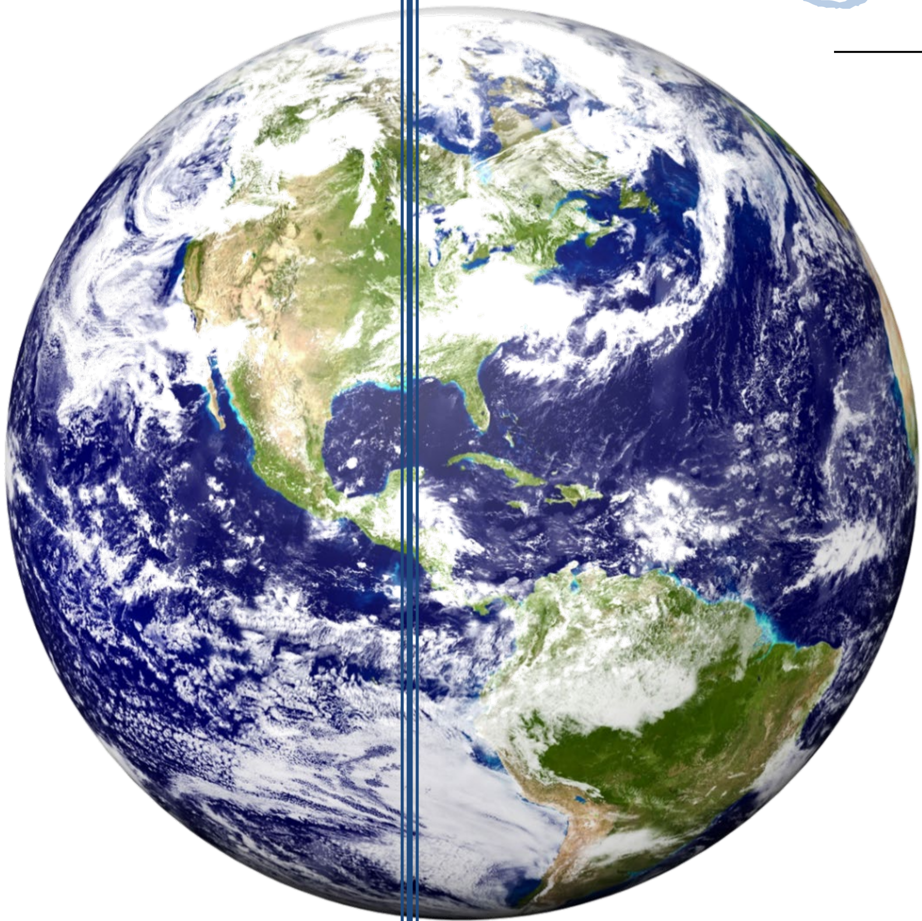
EARTH & PLANETARY SCIENCES

AT HARVARD UNIVERSITY



2026 Senior Thesis Presentations

Elisabeth Ngo

PhannyPacc Phan

Logan Wilson

Tyler Ory

Anika Hatzius

Isabella Cao

Sophie-An Kingsbury

Thursday, April 30th, 2026 10:30 am-12:50 pm
Haller Hall, Geological Museum 102

Please join us for an Undergraduate End-of-Year Reception beginning at 1:00 pm in the Student Lounge (4th Floor, Hoffman Labs).

WELCOME

Message from the co-Head Tutors 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 firsthand 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. These theses and today's presentations reflect the academic excellence and dedication of these students. Their efforts would not be possible without the support of faculty advisors, graduate students, post docs, fellow undergraduate students, and family. We thank these mentors and friends and congratulate our seniors on their achievement.

Roger Fu and Ann Pearson
Co-Head Tutors

Chloe Anderson and Esther James
EPS Preceptors

Roger Fu, Ann Pearson, Rebecca Fischer
Undergraduate Curriculum Committee

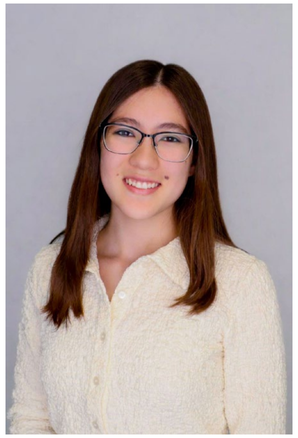
Campbell Halligan
Academic Programs Manager

Please join us for a reception honoring
all of our EPS Undergraduates
1:00 pm
Student Lounge
4th Floor, Hoffman Labs

Thank you for your support!

Elisabeth Ngo

Concentration: Anthropology and Earth and Planetary Sciences and Physics



Aztec Tradition, Contemporary Trouble: The Rise and Degradation of Chinampa Agriculture in the Basin of Mexico

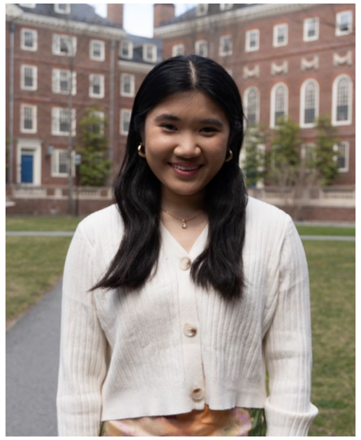
Advisors: **William L. Fash**, Bowditch Professor of Central American and Mexican Archaeology and Ethnology

The Basin of Mexico is home to chinampas, a system of agricultural fields constructed and cultivated within lakes. These seemingly floating fields are rooted to lakebeds by ahuejote willow trees and surrounded by canal networks. Once extensively used by the Aztecs for their high productivity and potential drought resilience, the chinampas have now been largely abandoned. Via analysis of historical and archaeological literature, an 1862 hydrographic map, and declassified HEXAGON satellite imagery from 1973-83, this thesis seeks to understand the pressures contributing to chinampa degradation in the Basin's Lake Xochimilco region — namely, flooding and urban development.

Though scholarship debates bottom-up influences on chinampa construction, it tends to focus on the fields' use as a collective system under top-down control. This thesis aims instead to further engage with individual and local community-level experiences and responses, drawing upon conversations with farmers and community members in the contemporary Basin of Mexico. Such discussions illuminate tensions surrounding tradition and change as well as misalignment between top-down influences and the needs of traditional chinampa farmers. This thesis argues that community-level involvement critically influences the resilience of the chinampa system and, in light of historical and contemporary water management concerns, could inform chinampa preservation strategies.

PhannyPacc Phan

Concentration: Earth and Planetary Sciences



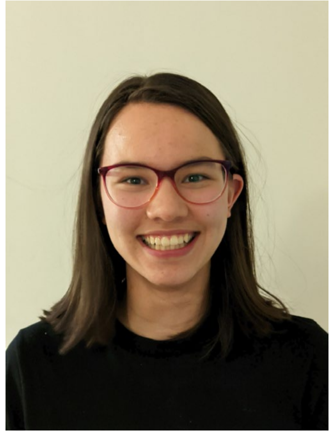
Serpentinization and H_2 Formation at the Pressure-Temperature Composition Conditions of Ocean Worlds

Advisor: **Rebecca Fischer**, Clare Boothe Luce Assistant Professor of Earth and Planetary Sciences

Serpentinization is a hydrothermal process in which the mineral olivine reacts with water to produce serpentine and secondary minerals such as magnetite, brucite, and talc. On Earth, it frequently occurs at plate boundaries, subduction zones, and mid-ocean ridges, playing a significant role in the transformation of the Earth's crust. This process can also generate molecular hydrogen (H_2), an important energy source in primitive metabolic pathways. This senior thesis specifically researched the process's capacity to occur at conditions found on Europa through experimental elemental compositions. Europa is one of Jupiter's largest moons, and for the past few decades, it has been the center of many astrobiology discussions. One of its most promising life-supporting features is its briny subsurface ocean. While the exact composition of Europa's ocean remains a widely debated topic in the field of astrobiology, an ocean with a $MgSO_4$ concentration is a possibility. This research specifically investigated how a 10 wt% $MgSO_4$ salt water solution impacts serpentinization at temperatures of ~ 473 K and pressures of ~ 200 MPa. Additionally, this research explored conducting low pressure-temperature experiments using diamond anvil cells (DACs), a tool more commonly known to be used for high pressure-temperature experiments. Preliminary results show a relationship between salinity and serpentinization reaction extent, but more experimental data and the capacity to actually measure H_2 gas is needed to support these findings.

Sophie-An Kingsbury Lee

Concentration: Earth and Planetary Sciences and Environmental Sciences & Engineering



Economic and Social Impacts of Air Pollution: A Causal Inference Approach

Advisor: **Francesca Dominici,** Clarence James Gamble Professor of Biostatistics, Population, and Data Science

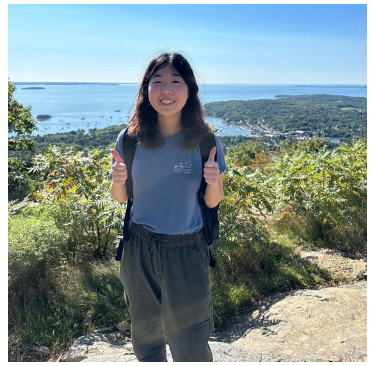
Air pollution remains one of the most pervasive and consequential public health threats of the 21st century. Among various pollutants, fine particulate matter less than 2.5 micrometers in diameter ($PM_{2.5}$) is of particular concern because its small size allows it to bypass natural defenses and penetrate deep into the respiratory system and bloodstream. As such, $PM_{2.5}$ exerts far-reaching biological and, consequently, social effects. As global urbanization, industrialization, and fossil fuel consumption continue to intensify, $PM_{2.5}$ exposure poses profound consequences for health, productivity, and economic opportunity.

Using high-resolution data from 70,185 census tracts in the contiguous United States, our research investigates the relationship between early-life $PM_{2.5}$ exposure in 1982 and absolute upward mobility (AUM) 30 years later for children born into low-income families. By applying advanced causal inference techniques---including entropy balancing, inverse probability of treatment weighting (IPTW), and generalized propensity score (GPS) matching—the study rigorously adjusts for demographic, socioeconomic, and environmental confounders.

Our findings reveal a consistent negative relationship: a one-standard-deviation decrease in childhood $PM_{2.5}$ exposure is associated with an approximately 4.9% increase in adult AUM. Furthermore, the analysis identifies significant spatial heterogeneity, with certain regions in the South, Midwest, and Pacific disproportionately affected. These results suggest that air pollution acts as a fundamental determinant of opportunity, quietly constraining the life chances of low-income children and reinforcing the need for better air quality monitoring and spatially targeted environmental and social policies.

Isabella Cao

Concentration: Earth and Planetary Sciences and Physics (Secondary)



Hydrothermal Carbonates of the Archean M2v Member: A Petrographical, Geochemical, and Stable Isotopic Analysis

Advisor: **Nadja Drabon**, Assistant Professor of Earth and Planetary Sciences

Roger Fu, Professor of Earth and Planetary Sciences

Carbonatization, the precipitation of carbonate minerals through hydrothermal processes, is a pervasive yet poorly understood phenomenon in Archean. Despite this, the carbon cycle's impacts on global habitability and the increased relevance of abiotic carbonate precipitation in the early Earth makes the Archean one of the most important time periods in which to study carbonates.

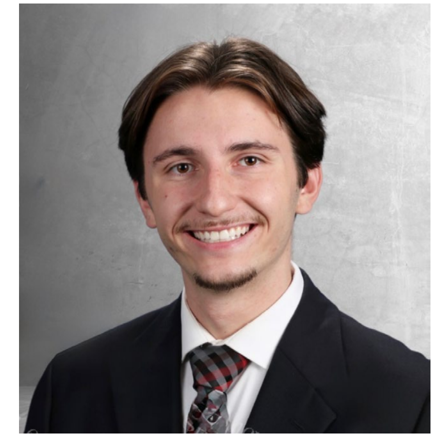
The goal of this study is to constrain the formational conditions of hydrothermal carbon- ates in the M2v member of the Barberton Greenstone Belt in South Africa. Specifically, we study the alteration sequence at the top of the M2v member, where fluid-rock interactions have led to extensive alteration in originally komatiitic rocks.

We utilize a combination of detailed petrographical analyses, whole rock geochemistry, and stable isotopic tools to constrain the timing of carbonatization, the chemical composition of the carbonates, and the temperature at which carbonatization occurred. Furthermore, we investigate relationships between carbonatization and broader depositional conditions such as the depth of alteration and the potential sources of carbon and other elements.

The results of our study demonstrate that carbonatization is a multi-stage process resulting in the chemically homogeneous precipitation of ferroan dolomites in both vein and matrix- hosted phases. The degree of carbonatization within the flow-top alteration zone is highly heterogenous, and associated with conditions such as the depth below seafloor and presence of other alteration phases (namely silica). Stable carbon isotopes indicate that the carbon hosted within the carbonates is consistent with an abiotic, marine source. The formation temperature, estimated using stable oxygen isotopes, ranges from 48 to 152^{o}C depending on the assumed isotopic composition of Archean seawater and is consistent with previously observed low-temperature hydrothermal systems near the study location. Our results open the door for further research inquiries into the temporal relationships between the observed alteration phases and potential impacts similar systems may have on the global carbon cycle.

Logan Wilson

Concentration: Astrophysics and Earth and Planetary Sciences



Protoplanetary Disk Inheritance and the Evolution of Small-Exoplanet Atmospheres

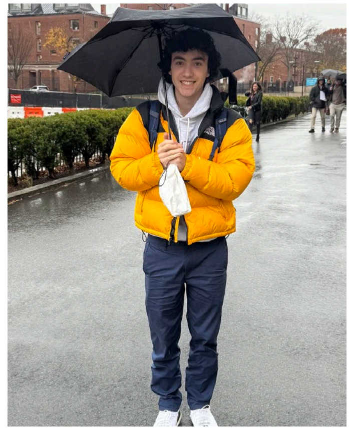
Advisor: **Robin Wordsworth,** Gordon McKay Professor of Environmental Science and Engineering; Professor of Earth and Planetary Sciences

Collin Cherubim, EPS Graduate Student – Wordsworth Group

Small planets' atmospheres are shaped by multiple physical processes, including their birth in a disk of gas and dust, and billions of years of evolution that follow. This thesis explores the link between a planet's chemical inheritance at birth and its final state. By modeling both atmospheric loss and interactions with a planet's molten interior, we reproduce the observed trends, validating the importance of the underlying physics of our model. We also show that a planet's ability to retain its atmosphere depends on its star's unique radiation history. Chemically, carbon serves as a reliable fingerprint of a planet's birth location, whereas oxygen levels are often more modified by the planet's molten surface. Attempting to observe both carbon and oxygen with telescope measurements may allow us to infer where a small-exoplanet formed, which was previously thought to be impossible due to the very evolutionary processes that we account for. Finally, we find that oxygen-rich atmospheres can form naturally without life. Therefore, to correctly detect true signs of life, we must understand a planet's formation context and subsequent evolution. By connecting current planets to their origins, this work helps us to understand the diversity of worlds in our galaxy.

Tyler Ory

Concentration: Earth and Planetary Sciences and Government (Secondary)



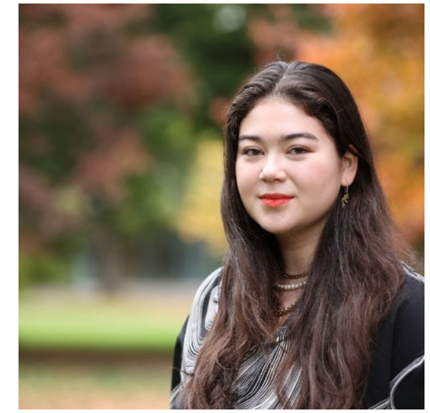
Exploring Stratospheric Polar Vortex Regimes and Associated Midwinter Surface Variability

Advisor: **Zhiming Kuang**, Gordon McKay Professor of Atmospheric and Environmental Science, Department of Earth and Planetary Sciences

The wintertime stratospheric polar vortex (SPV) is a major source of subseasonal atmospheric variability. Recent work has shown that regime-based frameworks can capture recurring structural differences in SPV behavior and their associated tropospheric impacts. This thesis examines whether a higher-order subdivision of SPV variability yields a more informative characterization of vortex structure than lower-order regime frameworks, and whether this structure can be reproduced in a climate model simulation. Using 6-hourly ERA5 geopotential height anomalies at 10 and 100 hPa during January and February, I identify recurrent SPV circulation states through principal component analysis and K-means clustering. I then examine their persistence, transition behavior, and coupling characteristics, as well as associated tropospheric and surface patterns. The ERA5 analysis identifies seven recurrent SPV regimes that span a strong-to-weak vortex family, including distinct displaced, elongated, and disrupted states. Several regime pairs with similar mean vortex strength show distinct signatures of contrasting eddy heat flux anomalies, 500 hPa circulation responses, and near-surface temperature and mean sea-level pressure patterns, while the reflection index shows weaker but still regime-dependent differences. The largest differences occur in the weak vortex pair E and F, which are associated with nearly opposite lower-stratospheric eddy heat fluxes and contrasting North American circulation and temperature anomalies. Strength-matched resampling further indicates that several circulation and surface anomalies are not reducible to vortex strength alone. Snowfall anomalies are weaker and less spatially coherent than the temperature and pressure responses. A parallel clustering analysis using Whole Atmosphere Community Climate Model (WACCM) output was conducted to assess the reproducibility of these regime distinctions in an independent climate model simulation. The model broadly reproduces the organization of SPV variability into recurring circulation states, but clustering diagnostics and cross-dataset pattern comparisons favor the five-regime solution over the seven-regime solution. The WACCM five-regime solution more closely resembles the ERA5 five-regime structure than the two seven-regime solutions resemble one another. These results indicate that regime-based analysis provides a useful framework for organizing SPV variability, but that five regimes offer the more robust large-scale characterization of the state space.

Anika Hatzius

Concentration: Earth and Planetary Sciences and Mathematics



Tropical Telegraph: Madden–Julian Oscillation-Linked Modulation of North Pacific Atmospheric Rivers in Reanalysis and Superparameterized Climate Simulations

Advisor: **Zhiming Kuang**, Gordon McKay Professor of Atmospheric and Environmental Science, Department of Earth and Planetary Sciences

Every year, the amount and distribution of rainfall along the North American West Coast shapes the lives of tens of millions of people. Much of this rainfall arrives in concentrated bursts carried by atmospheric rivers (ARs): long, narrow corridors of intense moisture transport that can deliver both vital precipitation and catastrophic flooding. Although seasonal forecasting has improved considerably in recent decades, many high-impact weather events occur on a subseasonal (2–6 week) window, when weather models become less reliable and climate signals are not yet dominant.

This thesis asks whether a large-scale tropical weather pattern called the Madden-Julian Oscillation (MJO), which circles the globe on a 30–60 day cycle, can improve subseasonal prediction of AR activity along the West Coast. Four decades of observational data show that the MJO offers conditional predictability of whether and where AR landfall occurs; the strongest effect is on the most hazardous ARs, whose occurrence probability rises by a factor of 1.75–2 with a latitudinal shift of as much as 4–6 degrees. Testing an analogous climate model simulation broadly reproduces this pattern, but overestimates how long the elevated-risk window persists, a bias that could lead model-based forecasts to overstate useful lead time.