The Adolph C. and Mary Sprague
MILLER INSTITUTE
for Basic Research in Science

Newsletter
Spring 2019

Interpreting contemporary trends in atmospheric methane

Miller Fellow Focus: Alex Turner

Most people have heard about the dramatic rise in greenhouse gas concentrations and their influence on our climate. They have probably seen the classic "Keeling Curve" that shows atmospheric measurements of carbon dioxide (CO_2) from the Mauna Loa Observatory on the island of Hawaii dating back to 1958. But what many people have not heard about is the enigmatic trends that we've observed over the past few decades in atmospheric methane (see the inset of **Figure 1**). Understanding the processes driving these contemporary trends in atmospheric methane is part of what I've worked on as a Miller Fellow at UC Berkeley. Specifically, my work has largely centered around quantifying the role of changes in the chemistry of our atmosphere on contemporary methane trends.

Atmospheric methane accounts for more than one quarter of the anthropogenic radiative imbalance since the pre-industrial. Its largest sources include both natural and human-mediated pathways: wetlands, fossil fuels (oil/gas and coal), agriculture (livestock and rice cultivation), landfills, and fires. The dominant loss of methane is through oxidation in the atmosphere via the hydroxyl radical (OH). Apart from its radiative effects, methane impacts atmospheric chemistry and our air quality by changing the oxidative capacity of the atmosphere and background ozone levels. As such, changes in the abundance of atmospheric methane can have profound impacts on the future state of our climate. Understanding the sources and sinks of atmospheric methane is critical to assessing both future climate and air quality.

From ice core records, we know that pre-industrial atmospheric methane levels were stable at ~600-700 ppb (see **Figure 1**) and have nearly tripled since 1800. Methane concentrations have been altered by agricultural practice and draining wetlands even before the industrialization but began increasing more rapidly in the 1900s due to expansion in both agricultural activities and the use of fossil fuels. This rapid rise closely mirrors other greenhouse gases that are driven by industrialization and agriculture (e.g., CO_2). There is no debate about the cause of the bulk of this rise in atmospheric methane from pre-industrial times to the present: human activities.

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For more information on all our programs online: miller.berkeley.edu & on PAGES 2 & 3.

"The Miller Visiting Professorship at UC Berkeley has been one of the most rewarding experiences in my entire scientific career. I recovered the scientific spirit and enthusiasm that made me go into science in the first place. I am very thankful to the Miller Institute for giving me this opportunity and would like to also specially thank Kathryn Day and her team for their superb work at organizing all the bureaucracy and the social activities."

- Natalia Requena Sanchez
Visiting Miller Professor Fall 2018,
Karlsruher Institut fur Technologie

Call for Miller Professor Applications

Online Application Deadline: September 12, 2019

Miller Research Professorship AY 2020-2021

The Miller Professorship program is looking with a view to the future in announcing the call for applications for terms in 2020-2021. The goal is to accommodate a greater range of campus faculty to participate in the vibrant Miller community. The objective of the Miller Professorship program is to provide opportunities for faculty to pursue new research directions on the Berkeley campus. For some, this may best be enabled by taking time off from teaching. This continues to be an option. For others, the teaching obligations are critical to maintaining campus academic programs. There is thus a second option for Miller Professors, allowing the continuation of campus service and teaching. Funds will be distributed differently depending upon the choice selected. Details of the terms and the application procedure are posted on the Miller Institute website. The primary purpose of the Miller Professorship program and the evaluation criteria will continue to be research excellence. Proposals to write books are not viewed as competitive. Applicants are encouraged to describe their interest in participating in the Miller Institute community.

Beginning May 2019 applications will be accepted from UC Berkeley faculty only for terms in the 2020-2021 academic year. The purpose of the Professorship is to allow members of the faculty to pursue new research directions on the Berkeley campus. Appointees are encouraged to follow promising leads that may develop in the course of their research.

Applications are judged competitively and are due by September 12, 2019. It is anticipated that between five to eight awards will be made.

Call for Visiting Miller Professor Nominations

Online Nomination Deadline: September 13, 2019

Visiting Miller Research Professorship AY 2020-2021

The Advisory Board of the Miller Institute for Basic Research in Science invites Berkeley faculty to submit online departmental nominations for Visiting Miller Research Professorships and the Gabor A. and Judith K. Somorjai Visiting Miller Professorship Award for terms in Fall 2020 or Spring 2021. The purpose of these Visiting Miller Professorships is to bring promising or eminent scientists to the Berkeley campus on a short-term basis for collaborative research interactions. It is required that awardees are in residence at Berkeley during their appointment term. Faculty members or research scientists from any place in the world are eligible to be considered for sponsorship. Non-US citizens must be eligible for J-1 Scholar visa status. Faculty members at other UC campuses are eligible to be nominated for this program. The Miller Institute, as the sponsor and administrative department, will extend an invitation after advising the department of its selection.

Any questions regarding this program may be directed to the Institute's office by phone at (510) 642-4088 or by emailing the Miller Institute.

:: **Nomination & Application details**: miller.berkeley.edu

:: **Questions?** 510-642-4088 | millerinstitute@berkeley.edu

The Adolph C. and Mary Sprague
Miller Institute for Basic Research in Science

Call for Nominations: Miller Research Fellowship

2020-2023 Term

Nomination Deadline: September 10, 2019

The Miller Institute for Basic Research in Science invites department chairs, faculty advisors, professors and research scientists at institutions around the world to submit nominations for Miller Research Fellowships in the basic sciences. The Miller Institute seeks to discover and encourage individuals of outstanding talent, and to provide them with the opportunity to pursue their research on the Berkeley campus. Fellows are selected on the basis of their academic achievement and the promise of their scientific research. Miller Fellows also have a keen curiosity about all science and share an appreciation for an interdisciplinary experience. The Miller Institute is the administrative home department for each Miller Fellow who is hosted by an academic department on the Berkeley campus. All research is performed in the facilities provided by the UC Berkeley academic department. A list of current and former Miller Research Fellows can be found at: http://miller.berkeley.edu/fellowship/members/all-mf-by-name

Miller Research Fellowships are intended for exceptional young scientists of great promise who have recently been awarded, or who are about to be awarded, the doctoral degree. Normally, Miller Fellows are expected to begin their Fellowship shortly after being awarded their Ph.D. A short period as a post-doctoral fellow elsewhere does not exclude eligibility, but applicants who have already completed more than two years of post-doctoral experience are not eligible for nomination. **A nominee cannot hold a paid or unpaid position on the Berkeley campus at the time of nomination or throughout the competition and award cycle**. Nominees who are non-US citizens must show eligibility for obtaining J-1 Scholar visa status for the duration of the Miller Fellowship. Non-US citizens will be required to prove English language proficiency prior to award. The Miller Institute does not support H1B visa status. The Fellowship term must commence between July 1 and September 1, 2020. Eligible nominees will be invited by email by the Institute to apply for the Fellowship after the nomination has been reviewed. Direct applications and self-nominations are not accepted.

*All nominations must be submitted using the Online Nomination System at: http://**miller.berkeley.edu**

Nominators will need the following required information to complete the online nomination process:

- Nominee's complete full and legal name (do not use nicknames)
- Nominee's current institution
- Nominee's complete, current, and active E-mail address that will be valid through March 2019, current mailing address with postal code and telephone number
- Nominee's Ph.D. Institution and (expected) Date of Ph.D. (month & year required)
- Letter of recommendation and judgment of nominee's promise by the nominator (saved in PDF format). Letter must be specific to the Miller Fellowship, have a current date, and be on institutional letterhead. The Executive Committee finds it helpful in the recommendation letter to have the candidate compared with others at a similar stage in their development.
- Nominator's current active E-mail address, title, and professional mailing address (include zip code/campus mail code)

The Institute provides a stipend of $65,000 with annual 2% increases and an annual research fund of $10,000, for total initial compensation of $75,000. There is provision for travel to Berkeley for Miller Fellows and their immediate families and a maximum allowance of $3,000 for moving personal belongings. Benefits, including medical, dental, vision and life insurance are provided with a modest contribution from the Miller Fellow. All University of California postdocs are represented by the UAW. Fellowships are awarded for three years, generally beginning August 1, 2020 and ending July 31, 2023. Approximately ten Fellowships are awarded each year. Candidates will be notified of the results of the competition starting in mid-December, and a general announcement of the awards will be made in the spring.

We are grateful for your thoughtful participation in this process and hope that you regard the time you may devote to this effort justified by the contribution you will be making to the careers of distinguished young scientists.

MILLER INSTITUTE FOR BASIC RESEARCH IN SCIENCE
Berkeley, CA 94720-5190
ph: 510-642-4088 | fax 510-643-7393
miller.berkeley.edu

Miller Research Fellowship Awardees 2019-2022

The Miller Institute is pleased to introduce the 2019-2022 Miller Research Fellows. Each year, the Miller Institute seeks to discover individuals of outstanding talent and to bring to Berkeley young scholars of great promise. Candidates are nominated for these awards and are selected on the basis of their academic achievement and the potential of their scientific research. The Fellows will be working with Berkeley faculty hosts for a three-year term beginning in the 2019 academic year. A full list of all past and present Miller Fellows is available on our website.

Allison Gaudinier

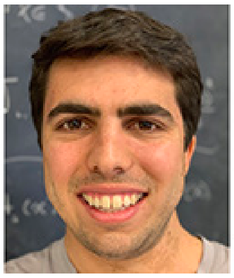
Ph.D. - UC Davis

Berkeley Dept. - PMB / Statistics

Faculty Host: Benjamin Blackman

Genetic variation and phenotypic plasticity allow species to adapt to local environments, especially in the face of climate change. My research focuses on exploring local adaptation of monkeyflowers. For plants, the timing of the developmental transition from a vegetative to reproductive life stage is critical for sufficient seed production. Monkeyflower populations from regions of low and high elevations in California and Oregon use critical photoperiod as a cue to regulate flowering time. I am dissecting how changes in regulatory pathways have adapted in these local populations to plants can survive their environments using different genetic mechanisms.

Reza Gheissari



Ph.D. - Courant Institute, NYU

Berkeley Dept. - Mathematics / Statistics

Faculty Hosts: Alistair Sinclair

Much of statistical physics is concerned with developing a microscopic justification for emergent phenomena and sharp phase transitions in matter (e.g., crystallization, spontaneous magnetization). I work on mathematical aspects of this theory from a probabilistic point of view, analyzing the equilibrium and off-equilibrium behavior of large, random, systems of interacting particles. I am also interested in relations to the theories of optimization and statistical inference in high dimensions.

Yu He

Ph.D. - Stanford

Berkeley Dept. - Physics

Faculty Host: Robert Birgeneau

Our physical world can be loosely divided into fermions and bosons, where the former make matter, and the latter facilitate interactions. My research uses light-matter interaction - in particular photoemission, neutron and x-ray scattering - to investigate both the fermionic and bosonic constituents in various functional material systems. Specifically, I work on solving the cuprate high-temperature superconductivity enigma, quantum criticality under random field, and emergent material interface phenomena.

Daniel Ibarra

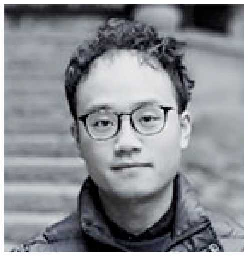
Ph.D. - Stanford

Berkeley Dept. - EPS

Faculty Host: Daniel Stolper

I am a geochemist and climate scientist working on the water and carbon cycles in terrestrial environments. My work includes studying the response of past and present terrestrial landscapes to changes in climate using modeling approaches, geochemical measurements and field observations. Broadly speaking, I am interested in the role that Earth's continents play in modulating habitable surface conditions over geologic time.

Pengfei Ji



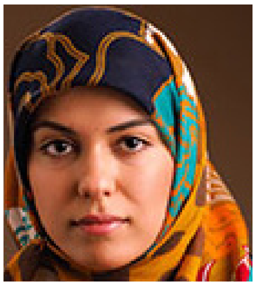
Ph.D. - University of Chicago

Berkeley Dept. - Chemistry

Faculty Host: John Hartwig

Natural metalloproteins contain only a small subset of the transition metals (e.g. iron, copper, zinc) in their structures, leaving behind most elements in the periodic table that catalyze crucial chemical reactions. Some metals are non-biological because they are unavailable to organisms. For example, many precious metals, such as ruthenium, palladium and iridium, have been shown by chemists to be the most active catalysts for a wide range of industrially relevant reactions. However, no enzymes contain these metals because they mainly exist in nature as insoluble alloys and in low abundance. With advances in chemistry and bioengineering, we will merge synthetic complexes of non-biological metals with protein architectures to create artificial enzymes that catalyze unprecedented processes in the well-defined binding sites of enzymes.

Seyedeh Mahsa Kamali

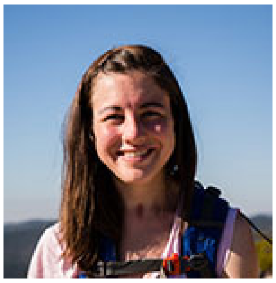


Ph.D. - Caltech

Berkeley Dept. - Bioeng / EECS

Faculty Hosts: Aaron Streets / Connie J. Chang-Hasnain

I am passionate about developing disruptive future technologies and tackling real-world challenges using on-chip nano-opto-electronic systems. My research interest lies at the intersection of optics, electromagnetics, nanotechnology, and materials science to design and develop novel miniaturized integrated optical systems with planar form factors and new functionalities. My vision is to develop new compact and highly versatile systems for hand-held biomedical devices, lab-on-chip microfluidic large-scale integration, and fluorescence microscopy. To this end, I plan to make use of my expertise in nano-optics that I have developed at Caltech, and combine it with microfluidics, active on-chip components, and various microscopy techniques that I plan to investigate as a Miller Fellow at UC Berkeley.



Naomi Latorraca

Ph.D. - Stanford

Berkeley Dept. - MCB

Faculty Host: Susan Marqusee

Proteins embedded in cell membranes relay information about the external environment into the cell, allowing the cell to respond—by changing gene transcription levels, protein expression, and more. To communicate information across the membrane, these proteins change their shape. Such shape changes—or conformational changes—might enable the direct movement of nutrients and ions across the membrane or cause the membrane proteins to couple with cytosolic proteins. During my Ph.D. I used computer simulations to reveal what certain membrane proteins look like when they undergo these changes, allowing us to explain cellular level phenomena using atomic-level information. As a Miller Fellow, I hope to combine experimental and computational approaches to better understand how perturbations to protein's structure, including mutations to the protein's primary sequence, alter the dynamics and function of these and other proteins.

Aavishkar Patel

Ph.D. - Harvard

Berkeley Dept. - Physics

Faculty Host: Ehud Altman

I am a theoretical condensed matter physicist interested in strongly interacting many-body quantum systems, which determine the physics of several modern materials. My PhD research was focused on understanding the flows of charge and energy and the dynamics of quantum information in such systems. Taking inspiration from recent and upcoming experiments, I intend to further explore the non-equilibrium properties of these systems.

Ekta Patel

Ph.D. - University of Arizona

Berkeley Dept. - Astronomy

Faculty Host: Daniel Weisz

Tracking the 3-dimensional motions of stars in nearby galaxies is a recent astronomical breakthrough that has substantially increased our knowledge of how galaxies grow, evolve, and interact with each other over cosmic time. My research focuses on using such measurements to understand the history of the Local Group, which is composed of our Milky Way, its twin galaxy, Andromeda, and the dozens of small "satellite" galaxies orbiting around each of them. These dynamical measurements now make it possible to trace the orbital histories of Local Group galaxies to their origins in the early Universe. In my work, I use the combined power of these observational data sets with data from high-resolution simulations of the Universe to uncover the dynamical history and future fate of our galactic neighborhood.

Danqing Wang

Ph.D. - Northwestern University

Berkeley Dept. - MSE

Faculty Host: Junqiao Wu

The rapid development in nanoscience not only enables access to physical sizes at a smaller scale, but also triggers fundamental breakthroughs in such as optics, electronics and energy. My Ph.D. research focused on structural engineering of photonic nanocavities for tunable nanoscale lasing, and the light-matter interactions with different gain materials. As a Miller Fellow, I plan to exploit materials development and structural designs for engineering optical behaviors at the nanoscale. I will aim at reconfigurable and tunable nanophotonics by utilizing phase-change materials and two-dimensional materials as new optical elements that are responsive to external stimulus. Also, I will expand my research scope to thermal and electronic properties of nanomaterials, and explore interactions at the quantum level.

Qiong Zhang

Ph.D. - University of Maryland, College Park

Berkeley Dept. - Bioeng / PMB

Faculty Hosts: John Dueber / Brian Staskawicz

I am a plant biologist aiming to 'evolve' better crops through molecular breeding facilitated by genome editing tools (such as CRISPR). I studied plant innate immunity during my Ph.D. and as a Miller Fellow, I'm developing CRISPR tools to engineer crops with durable resistance against plant pathogens. Eventually, I hope to extend these methods to the improvement of other important agronomical traits.

Donations can be made by going to:
Give to CAL for the Miller Institute: **miller.berkeley.edu/gift**

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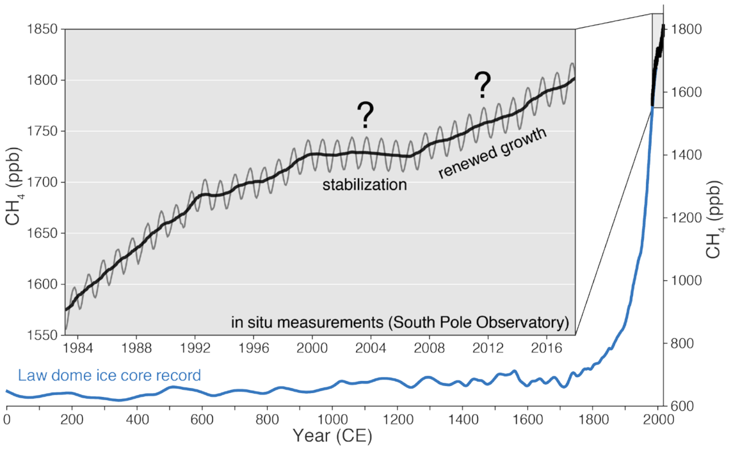

Figure 1: Observations of atmospheric methane over the past 2000 years. Law dome ice core record (blue) and direct atmospheric observations from the South Pole (gray, de-seasonalized in black). Adapted from Turner et al. (2019), PNAS, doi:10.1073/pnas.184297116.PNAS, 113(7), 1686-1688.

The first accurate in situ measurements were made in 1978 and monitoring networks reached global coverage in 1983. These measurements showed a continued increase (with fluctuations) until 2000 when the globally-averaged concentration stabilized at ~1750 ppb. In 2007 atmospheric levels began increasing again, with this rise continuing today. There has been much speculation as to the cause of these recent trends with numerous seemingly contradictory explanations. Hypotheses for the trends have invoked changes in tropical wetlands, livestock, fossil fuels, biomass burning, and the methane sink. Attribution of these trends has proven to be a difficult task because: (1) this period of renewed growth is characterized by a source-sink imbalance of only 3% and (2) because there are a myriad of diverse processes with large uncertainties that could potentially emit methane.

Explanations of recent atmospheric methane trends can be broadly grouped based on the types of proxy measurements used. Measurements of $\delta^{13}C\text{-}CH_4$ (the $^{13}C/^{12}C$ ratio in atmospheric methane) provide information about the fraction of methane coming from biotic (i.e., microbial) and abiotic sources, as biotic methane is produced enzymatically and tends to be depleted in ^{13}C, making it isotopically lighter. Atmospheric ethane (C_2H_6) can be co-emitted with methane from oil/gas activity and, as such, has been used as a tracer for fossil methane emissions. Methyl chloroform (CH_3CCl_3) is a banned industrial solvent that has been used to indirectly infer the abundance of the dominant methane sink (the hydroxyl radical, OH). These three measurements ($\delta^{13}C\text{-}CH_4$, C_2H_6, and CH_3CCl_3) have been used in conjunction with atmospheric methane measurements. However, studies generally reached differing conclusions regarding the recent methane trends.

Figure 2 shows the observations of atmospheric methane and the proxies used to explain the stabilization and renewed growth. Studies using ethane have argued that decreases in fossil fuel sources led to the stabilization of atmospheric methane in the 2000s and that increases in fossil fuel sources contributed to the growth since 2007. Studies using isotope measurements tend to find that decreases in microbial sources led to the stabilization and increases in microbial sources are responsible for the renewed growth. Studies that include methyl chloroform measurements tend to find that changes in the methane sink played a role in both the stabilization and renewed growth.

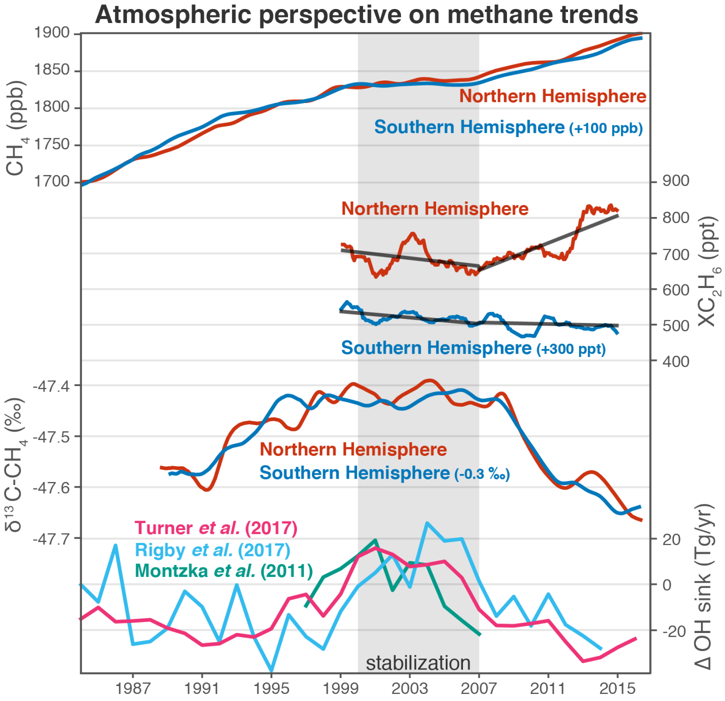

Figure 2: Constraints on atmospheric methane over the past 40 years. Illustrates our atmospheric constraints on the contemporary methane trends from: methane, ethane, $\delta^{13}C\text{-}CH_4$, and OH sink inferred from methyl chloroform observations. Adapted from Turner et al. (2019), PNAS, doi:10.1073/pnas.184297116.

Most studies on methane trends have focused on methane sources and neglected changes in the methane sink (OH). However, my previous work showed how changes in the methane sink could largely explain the contemporary trends in atmospheric methane (see bottom row of **Figure 2**) but did not identify a mechanism for the changes in chemistry. As part of the Miller Fellowship, I have shown how well characterized climate oscillations like the El Niño—Southern Oscillation (ENSO) can induce changes in globally-averaged OH and, in turn, trends in atmospheric methane. This is because, to first order, globally-averaged OH concentrations are controlled by the ozone photolysis frequency, specific humidity, sources of NO_x, and sources of CO and hydrocarbons:

$$[\mathrm{OH}] \propto \overset{\text{ozone photolysis}}{J_{O_3}}\,\underset{\text{specific humidity}}{q}\,\frac{\overset{\text{source of NO}_x}{S_N}}{\underset{\text{source of CO and hydrocarbons}}{S_C^{3/2}}}$$

Celebrating Kathy Day

It is with mixed emotions and sincere gratitude for her 30 years of leadership at the Miller Institute that we are announcing the retirement of the Chief Administrative Officer Kathy Day in June of this year.

Kathy started with the Miller Institute in 1989. Under her guidance, the Miller Fellowship expanded from 2 years to 3 years to adapt to the changing standards of the academic market place. She also helped hatch the Annual Symposium, the Miller Senior Fellows program, and the Happy Hour, all of which have been hugely popular. She judiciously added two additional staff positions to make the Miller Institute one of the smoothest sailing organizations on campus.

But these administrative accomplishments fail to capture the ineffable range of contributions Kathy has made to the Institute. Indeed, for many of us, Kathy IS the Miller Institute. She is respected and appreciated by everyone associated with the Institute. Kathy is a constant source of valuable information both for the faculty and the fellows. She is always responsive to professional and personal needs of awardees enabling maximum benefit from their time with the Miller Institute. Importantly, she fosters a close professional relationship between the Institute and thought leaders from all branches of science via regular newsletters, emails and the "Kathy Day Magic". In short, she makes all of us feel incredibly special. We can think of no better example of her appreciation than a great honor that befell Kathy a few years ago, which is that a former fellow named a new species of amphibian after her (***Anolis kathydayae***). We doubt that any Chief Administrative Officer has received a comparable honor in the history of UC Berkeley!

Kathy plans to spend her retirement traveling, going to Warriors games and coming back to help the Miller Institute when we need her.

Save the Date!

We will be honoring Kathy at a special reception on May 10, 3-5 pm at the Alumni house on the UC Berkeley campus.
RSVP to eedouglass@berkeley.edu.

On behalf of everyone here at the Miller Institute, we will miss Kathy dearly and wish her the best of luck.

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My work showed how the La Niña phase of ENSO is associated with an increase in convection in the Tropical Pacific, which increases the occurrence of lightning and, consequently, allows for more OH production via NO_x. This finding helps provide a mechanistic link as to why the methane loss rate may have changed and, in turn, what may be driving the contemporary methane trends.

We still do not have a definitive answer as to what processes drove the recent trends in atmospheric methane, which continues to fuel my interest in the topic; however, the uncertainty in processes driving the recent methane trends should not detract from the important role of methane in climate change and the potential for mitigating methane emissions from human activities. There is no question that the increasing trend in atmospheric methane since the 1800s is due to human activities and reducing those anthropogenic methane emissions will ultimately slow or reverse the rise in atmospheric methane concentrations.

Alex Turner was born in Cambridge, Massachusetts and grew up in Boulder, Colorado. Growing up in Boulder helped foster a love of the environment and the outdoors. Alex received his BS in Mechanical Engineering from the University of Colorado at Boulder in 2012 before returning to Cambridge where he received his PhD in Atmospheric Chemistry from Harvard in 2017, advised by Professor Daniel Jacob. Alex arrived at Berkeley in the Fall of 2017 as a Miller Fellow where he is jointly advised by Ronald Cohen and Inez Fung in the College of Chemistry and Department of Earth and Planetary Science, respectively. During the summer Alex spends his free time rock climbing, backpacking, and trail running; in the winter he enjoys skiing and telemarking.

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Miller Institute News - Spring 2019
Please send address corrections to:
miller_adm@berkeley.edu

Trip to Año Nuevo 2019

(see more past & current Miller Events: http://miller.berkeley.edu/events/miller-events)

Birth Announcements

Alejandro Rico-Guevara (Miller Fellow 2017-2020) and his wife, Kristiina Hurme welcomed their second daughter, Aurora Delta Rico Hurme, born February 2019.

Online Newsletter

The Miller Institute invites you to enjoy our previous e-newsletters by visiting: http://miller.berkeley.edu/news/newsletters

The Miller Institute is "dedicated to the encouragement of creative thought and the conduct of research and investigation in the field of pure science and investigation in the field of applied science in so far as such research and investigation are deemed by the Advisory Board to offer a promising approach to fundamental problems."

For More Information:

+ Staff: Kathryn Day, Donata Hubert, Erin Douglass & Emily Birman