ACMG Undergraduate Research Symposium 2023

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High Resolution Methane Emissions in India and Bangladesh Inferred From an Iterated Inversion with 2022-2023 TROPOMI Data

Alex Alonso

Methane (CH_4) is a greenhouse gas with a 20-year warming potential 80 times that of CO_2 and has caused 30% of global warming observed to date. Methane emissions in India and Bangladesh have experienced significant growth in recent decades, largely due to the expansion of industrialization and agricultural activities. However, bottom-up estimates of methane emissions in the region are highly uncertain due to a high prevalence of unregistered smallholder farms, rural isolation, and large spatial variations in farming practices and climate. Here we perform a top-down inverse analysis of TROPOMI satellite data to improve methane emissions estimates over India and Bangladesh from October 2022 to April 2023. To do so, we apply the Integrated Methane Inversion (IMI) in a Kalman filter framework to calculate monthly emissions at up to 0.25°x0.3125° resolution. We exploit an ML-based blended TROPOMI+GOSAT data product which reduces biases in the TROPOMI retrieval. We find total posterior emissions in the region to be significantly higher than prior emissions. Upward corrections are highest in northern India and Bangladesh (the Indo-Gangetic Plain) where emissions are highest, which we attribute to livestock, wastewater, and rice paddies. Methane emissions are highest in October, driven by rice and livestock, and generally decrease over time until April. Our results show the scale and (temporal and spatial) variability of methane emissions in India and Bangladesh, as well as the varying accuracy of bottom-up estimates across the region. This study demonstrates the importance of continued satellite monitoring and correction of seasonal emissions in a warming and increasingly unpredictable climate.

Uncovering latent VOC emissions and spatiotemporal drivers of urban ozone in changing NO_x regimes: A data-driven case study of Los Angeles and Chicago

Christian Chiu

Surface ozone pollution in the United States has increased over the past two decades, despite steady reductions in nitrogen oxide (NO_x) emissions. Both NOx and volatile organic compounds (VOCs) have large anthropogenic sources from combustion, while VOCs also have biogenic sources as well as fugitive industrial and residential sources. Historically, ozone formation in urban areas occurred under VOC-limited conditions in the US. However, effective emission reductions have led to transitions into NOx-limited regimes today in large cities such as Los Angeles and Chicago. Here, we use a long-term (2000-2016) daily 1 km^2 dataset of ozone, NO_2, and fine particulate matter ($PM_{2.5}$) concentrations derived from observations to identify areas within these urban domains that exhibit high ozone production efficiency across space and time. We employ data-driven modal decomposition techniques to uncover VOC emission sources contributing significantly to ozone production and to discover the evolving spatiotemporal drivers of urban ozone in these cities. We explore whether these ozone drivers are linked to emerging emission sources in Los Angeles and changing $PM_{2.5}$ composition and meteorology in Chicago. In contrast to traditional atmospheric chemistry approaches which rely on relatively uncertain emissions and mechanisms in mechanistic models to interpret observational data, our study demonstrates the potential for data-driven approaches to directly uncover previously unknown or missing processes from data itself.

Quantifying Wildfire Smoke Exposure and Health Impacts in the Western United States

Karina Chung

Smoke particulate matter ($PM_{2.5}$) pollution from accelerating wildfire activity in the Western United States (WUS) poses a significant threat to public health, especially to low-income populations and to individuals with existing cardiovascular and respiratory conditions. However, in preparing for future fires, land managers face considerable challenges quantifying these health risks. We develop a novel framework to evaluate the gridded contributions from WUS wildfires to smoke exposure and health impacts in nine regions across the contiguous United States. This framework incorporates historical and projected fire emissions, land cover types, variability in fire recurrence, and wildfire smoke transport to generate a relative rank-based smoke risk index at 0.25° × 0.25° spatial resolution. Results from our risk index show that our projected high smoke-risk areas for 2018 and 2020 align well with ground-truth burned area data for the 2018 and 2020 fire seasons and correctly predict high fire risk zones. In the 12 months following the 2020 fire season, we estimate that excess mortality in the Western United States attributable to smoke $PM_{2.5}$ exposure approached 50,000 deaths. We deploy the risk index on an online software tool, allowing land managers to analyze smoke risk under various scenarios of burned area and fuel consumption. Ongoing and future work includes conducting further scenario analyses and developing mortality estimates for individual large fires. Ultimately, use of our risk index will enable land managers to direct fire prevention resources towards areas that contribute heavily to smoke exposure, furthering efforts to safeguard low-income communities and other high-risk populations from excess smoke $PM_{2.5}$ exposure.

Spatial and Temporal Differences in NO_2 Column Densities and Implications for Geostationary Satellite Product Applications Across Asia

Lucy Gagnon

Nitrogen oxides ($NO_x \equiv NO + NO_2$) enter the atmosphere by emission from fuel combustion and natural sources, and these chemical species significantly impact air quality, health, climate forcing, and nitrogen deposition. Pandora instruments are ground-based spectrometers which allow for identification of the drivers of the observed diurnal variation in Pandora total column measurements of NO_2, as the total columns are not influenced by mixed-layer growth. Therefore, to identify whether chemistry, transport, or emissions drive diurnal NO_2 variation across Asia, we consider the behavior of NO_2 using total column measurements from Pandora spectrometers from June 2022 to May 2023. We determine hourly average NO_2 concentrations across several sites, with a focus on South Korea, and compare the seasonal and diurnal variations at these stations. We determine that anthropogenic emissions and nighttime chemistry play the largest role in morning NO_2 increases, and seasonal changes in the lifetime of NO_2 affect late afternoon NO_2 behavior. We also compare East Asian sites with those in Dhaka and Dalanzadgad and notice that differences in biomass burning and fuel sources significantly impact NO_2 seasonal and diurnal variation, respectively. From these Pandora measurement trends, we develop a reliable understanding of daily NO_2 behavior across sites in Asia, which is essential for informing future analysis using geostationary satellite constellations (GEMS over East Asia, TEMPO over North America, and Sentinel-4 over Europe) to elucidate diurnal NO_2 behavior with greater spatial coverage.

Emergency Mobile Monitoring for California Wildfire Smoke

Greta Schultz

Smoke from wildfires poses a severe threat to air quality, public health, and ecosystems across the United States, particularly in the Western region. Presently, air quality monitors throughout California remain stationary, resulting in reduced reliability, higher maintenance costs, and significant limitations due to their immobility. However, by devising a strategy to capture the spatial and temporal dynamics of smoke, we could embrace the adoption of more cost-effective, mobile monitoring systems. The California Air Resources Board (CARB) is confronted with a critical decision: how to strategically deploy emergency mobile sensors to effectively monitor human exposure to encroaching wildfires. This research aims to solve the mathematical challenge of optimizing the placement of mobile sensors along a path that captures the spatial extent and temporal evolution of smoke exposure. By utilizing data fusion techniques, greedy algorithms such as DMD and MrDMD, and advanced modeling, our objective is to surpass the performance of numerous stationary sensors, while utilizing a cost-effective approach through the integration of additional mobile monitors. Having fed the algorithm with $PM_{2.5}$ smoke concentration data spanning from 2006 to 2020, we find two distinct pathways across the Northern Cascades region and the Central Valley region near the Sierra Nevadas. By pinpointing these distinct routes, we can significantly enhance the accuracy of air quality monitoring while concurrently reducing costs. This optimization can be achieved by transitioning to a higher number of affordable mobile monitors, as opposed to relying on fewer, pricier, and less dependable stationary monitors. This sensor path planning proposal holds the potential to significantly impact CARB's resource allocation strategy, enabling them to make informed decisions. By enhancing our path planning methodologies, we can not only advance our understanding of air quality, but also make vast improvements in human health and the surrounding ecosystems that rely on it.