ACMG Undergraduate Research Symposium 2021

Session 1: Wednesday, August 4, 2021, 12-1pm

Marie Panday, Maggie Vallejo, and Lewis McAllister

US Trends in Wildfire Smoke derived from NOAA's Hazard Mapping System smoke product and Airport Data from 2010-2020

Marie Panday

The scale of wildfires and their associated smoke plumes have increased in the last four decades and have exacerbated the health risks for people living within wildfire-prone areas. While satellite imagery enables us to monitor the location, abundance, and severity of smoke, datasets such as NOAA's Hazard Mapping System (HMS) smoke product are unvalidated and may not reflect ground-level smoke conditions. We propose that airports monitoring the presence of smoke may offer a localized constraint on satellite smoke products. Our research aims to validate NOAA's HMS product by comparing how well the HMS smoke data agree with NOAA's Integrated Surface Database (ISD) of local, hourly airport data from 2010 to 2020 across the US. Our spatial and temporal analysis shows that the trend in the number of smoke days is similar between the two datasets. HMS smoke plumes are qualitatively categorized into 3 densities: light, medium, and heavy. Particularly, HMS smoke plumes with "medium or heavy" densities have the strongest correlation of r = 0.60 and a mean absolute error of 0.73. We observe the greatest difference in the airport and HMS-derived mean smoke days across the west and east coast, especially in California's Central Valley and eastern Washington. However, there is a very weak correlation of r = 0.17 between surface-level mean smoke days and from HMS "heavy, medium, or light" density smoke days. Further, using all HMS smoke densities tend to overestimate the trends in and magnitude of smoke days. Based on these results, NOAA's HMS product is somewhat consistent with trends observed at airports, but caution should be used in assuming equivalence with surface conditions in research investigating wildfire smoke and its consequences for public health.

Estimating $PM_{2.5}$ in Indigenous Territories in South America

Maggie Vallejo

There has been a rise in fire activity in the Brazilian Amazon as a result of deforestation to clear land for cattle and vegetation. Fires emit large amounts of particulate matter less than or equal to

2.5 microns in diameter ($PM_{2.5}$), which can cause respiratory and cardiovascular diseases. Many Indigenous people live in proximity near these fires, so the goal of this project is to quantify $PM_{2.5}$ concentrations in their territories. Using data from the AQUA satellite, we were able to analyze annual fire patterns in Brazil. Additionally, we used the Stochastic Time-Inverted Lagrangian Transport Model (STILT) coupled with FINN, GFED, GFAS, and QFED to simulate and estimate $PM_{2.5}$ concentrations in Indigenous territories neighboring fire hotspots. We looked at $PM_{2.5}$ concentrations during August 2019, which is part of the dry season when fire activity peaks. We ran the simulation on the Kayapó in Mato Grosso and Pará, the Xingu in Mato Grosso, and Kadiwéu in Mato Grosso do Sul in Brazil and the Guarayos in Santa Cruz, Bolivia. The westernmost location, Guarayos, had the highest $PM_{2.5}$ concentration of 232 $\mu g/m^3$ on August 11 when we averaged the concentrations from all four fire inventories. According to the World Health Organization (WHO), the 24-hour daily mean is 25 $\mu g/m^3$. Exposure to high amounts of $PM_{2.5}$ makes the Guarayos territory vulnerable to cardiovascular diseases at a disproportionate rate during the dry season. Furthermore, many Indigenous communities live far away from hospitals, which increases their risk for health issues.

Influence of pollutant transport from China on $PM_{2.5}$ pollution episodes over Korean cropland

Lewis McAllister

Long-distance transport of pollutants originally emitted in China to South Korea can account for a substantial amount of air pollution in Korea. The AirKorea surface network contains hourly air pollution data between 2015-2020 at 324 stations across Korea. From this dataset and wind reanalysis data, we define China-influenced days in Korea as those with both favorable winds and with elevated pollutant levels of two of SO_2, CO and NO_2 relative to the deseasonalized timeseries at an isolated Korean island station upwind of the peninsula. We found that China-influenced days have significantly greater $PM_{2.5}$ air concentration levels as compared to days without transport, with the difference especially pronounced at cropland sites in March. The cropland enhancement in $PM_{2.5}$ is not accounted for by similar increases in other pollutants such as SO_2 which implies the role of in-situ formation, such as ammonia-nitrate-sulfate processes resulting from local fertilizer application. However, there does not appear to be a strong correlation between the March $PM_{2.5}$ enhancement over the cropland sites and monthly ammonia concentrations calculated using the GEOS-Chem chemical transport model. Further work will be necessary to account for the seasonal enhancement, including analysis of revised ammonia emissions inventories such as MASAGE-NH3. Our findings are robust to many different definitions of China-influenced days, with 95 of 109 the days defined as China-influenced consistent across the daily deseasonalized, monthly deseasonalized, and no deseasonalization datasets. We plan on using the STILT particle dispersion model to further validate our definition, with particular attention paid to an exceptionally strong rural pollution episode in early March 2019.

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Session 2: Wednesday, August 11, 2021, 12-1pm

Alison Mangano, Samuel Lin, Margaux Winter, Daniel Shen, Kevin Luo, and Tina Chen

The Potential Sources and Sinks Responsible for the 2020 Increase in Methane Concentration

Alison Mangano

Methane is a very important anthropogenic greenhouse gas due to its heat trapping capabilities being 21 times greater than CO_2 in a 100-year span. Methane has 3 main sources which makes it difficult to determine which source is responsible for increases in atmospheric methane concentration. The sinks of methane, which consist primarily of chemical loss due to OH in the atmosphere, have large uncertainties, which also contributes to the difficulty of determining the cause of changes in methane concentrations. Methane has been on an upward trend called the renewed growth period since the 7-year stabilization period ended in 2007. In 2020 methane increases spiked to an all-time high since methane concentration data began being collected in 1983. Given methane's contribution to the climate crisis, determining which sources or sinks were responsible for the spike in methane concentration in 2020 is vital. To determine the source responsible, we will examine the changes in atmospheric concentrations due to Covid-19 and use atmospheric methane observations in 2019 and 2020 to investigate the causes of the spike in 2020. By determining the source responsible for the 2020 increase, we hope to inform methane regulations.

Optimal $PM_{2.5}$ Sensor Placement in the United States using modal decomposition techniques

Samuel Lin

Environmental monitoring of $PM_{2.5}$ in the United States relies heavily on a network of EPA monitoring sites. Data collected from these sites are used to assess air pollution impacts for public health and to validate satellite data and results from air quality models. However, the sensor measurements are sparse in both space and time due to the cost of maintaining sites, and optimizing sensor placement is a central mathematical challenge. By taking advantage of the underlying patterns found in the measurement data, we can identify the optimal minimal placement of sensors for maximum impact. To achieve this, we compare applications of principal component analysis (PCA) and multiresolution dynamic mode decomposition (mrDMD) on $PM_{2.5}$ data collected over 17 years (2000-2016). PCA is a widely-used data analysis technique that reduces the dimensionality of a dataset into representative features. MrDMD improves upon PCA by incorporating higher frequency time-scale components to capture transient pollution events averaged out by PCA. We find that while PCA scatters sensors uniformly across the United States, mrDMD clusters these sensors in areas of higher $PM_{2.5}$ variability. Using these optimized sampling locations and our modal libraries, we are able to offer full state reconstruction of national-scale $PM_{2.5}$. A comparison of these reconstructions suggests that mrDMD reconstructions are generally more accurate than their PCA counterparts. Our findings reveal that $PM_{2.5}$ is strongly influenced by high-frequency, transient events that span 1-4 weeks that mrDMD is able to capture better than PCA.

Source Attribution of Methane Emission using Multiscale Geographically Weighted Regression

Margaux Winter

Large uncertainties exist in the sources and sinks of methane emissions. Satellite observations of atmospheric methane concentrations can improve spatial estimates of methane emissions at coarse resolution through inverse analyses. However, methane emission sources are often co-located, complicating the attribution of inversion-derived emissions to specific sources. In this work, we define a method to improve source attribution of methane emissions. As a demonstration, we attribute emissions from a 2˚x2.5˚ resolution global inversion of 2019 TROPOspheric Monitoring Instrument (TROPOMI) methane observations to their source sectors. We identify grid cells with large discrepancies between the inverse solution and the prior estimate of methane emissions and with high information content as defined by the inversion's averaging kernel. Within these grid cells, we use oversampled TROPOMI observations at 0.1˚x0.1˚ resolution and methane emissions inventories at 0.1˚x0.1˚ resolution in a geospatial statistical method known as Multi-scale Geographically Weighted Regression (MGWR). MGWR identifies the correlation between atmospheric methane observations and the prior methane emission inventories as they vary across a grid cell. We use the MGWR output to attribute the inversion emissions to source sectors within the grid cell and compare the results to the source attribution derived by scaling the initial prior emissions inventory.

Improving Sentinel-2 Methane Retrievals over Heterogeneous Terrain

Daniel Shen

Satellite remote sensing is a widely used method of observing the physical properties of an area and its overlying atmosphere by measuring their absorption spectrum from above the atmosphere. Varon et al. (2021) showed that remote sensing by the Sentinel-2 satellites can detect methane point sources at fine resolution of 20 m and high revisit frequency of 2–5 days. One limitation of the retrieval method was its use of a single regression coefficient to define scene-wide brightness differences between two satellite passes and/or spectral bands. Though valid for quasi-homogeneous terrain with uniform surface properties, this yields inaccurate methane retrievals over complex, heterogeneous terrain. In this project, pixel-specific regression coefficients are introduced along with other modifications to improve Sentinel-2 methane retrievals over heterogeneous terrain. We find that these methods reduce retrieval noise by around 30% in a relatively uniform region of the Algerian Hassi Massaoud oil field (using 36 satellite passes from January 17, 2019 to January 17, 2020), 12% in a moderately heterogeneous region of the Permian Basin (June 26, 2020 to October 29, 2020, observed every 2.5 d), and 4% over a very heterogeneous region of the Permian Basin (June 1, 2021 to August 8, 2021, observed every 2.5 d). These improvements demonstrate the capability of Sentinel-2 and remote sensing in general to be a consistent, replicable, and robust technology for detecting and quantifying methane emissions.

Constructing an Observational Error Covariance Matrix for TROPOMI Methane Inversions

Kevin Luo

Constituting one fifth of global emissions, methane is the second most abundant anthropogenic greenhouse gas, behind only carbon dioxide. While its lifetime in the atmosphere of around ten years is much shorter than that of carbon dioxide, it is far more efficient at trapping radiation, leading to a 100-year global warming potential that is twenty-five times greater. Inverse analysis of methane concentration observations from the TROPOspheric Monitoring Instrument (TROPOMI) can help better quantify the global methane budget. Existing inversions assume a fully diagonal observational error covariance matrix, allowing for each observation to be ingested individually. We instead first measure a correlation decay length by aggregating error measurements by day and computing covariances between grid cells, and use it to implement an exponentially decaying covariance matrix. We then perform the inversion based on monthly averages, and compare the inversion results employing this matrix to existing ones.

Towards determining the impact of increasing ozone trends on crop yields in South Korea

Tina Chen

The past two decades have shown increasing ozone trends across all seasons in South Korea. Rising ozone concentrations pose a threat to both human health and agricultural production. Globally, high levels of ozone are responsible for 2-16% of yield losses across four major staple crops (wheat, rice, maize, soybean), with an economic loss of $14-16 billion USD each year. We aim to evaluate the impact of increasing ozone on key crop yields in South Korea. Using crop production surveys from the Korean Statistical Information Service, we identified rice, barley, and soybean as high acreage crops in South Korea. We implement a mixed effects regression model to determine the relationship between ozone concentrations and rice, barley, and soy yields from 2001 to 2019. We used a threshold value of 40 ppb, based on previous studies, to analyze the impact of ozone levels above this value. Our models suggest that exposure to concentrations above this threshold has negative impacts on yield and reductions in peak ozone levels can result in increased crop growth. However, there does not seem to be a strong correlation between ozone and crop yield due to limited data and timeframe. Further work will be necessary to identify a critical threshold for ozone concentration in South Korea and what percentage of variation in crop yield can be attributed to rising ozone levels.