**Southeast Michigan Health & Air Quality**

*Identifying Trends of Ground-level Ozone Precursors in Southeast Michigan and Northern Ohio*

**Project Team**

***Project Team***

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**Project Overview**

***Project Synopsis:***

Heavy industrialization has resulted in high ground-level ozone concentrations in southeast Michigan and northern Ohio. Ground-level ozone exposure is associated with an increased risk of many respiratory issues. To ultimately decrease the burden that ground-level ozone afflicts on the public health of the region, our project partnered with the Michigan Department of Environment, Great Lakes, and Energy’s (EGLE) Air Quality Division and the Lake Michigan Air Directors Consortium (LADCO), to investigate the usefulness of measuring ground-level ozone precursors from space. This project processed measurements of nitrogen dioxide (NO2), formaldehyde (HCHO), and methane (CH4) from Sentinel-5P Tropospheric Monitoring Instrument (TROPOMI) and Aura Ozone Monitoring Instrument (OMI) by oversampling on monthly, yearly, and 3-year scales to analyze pollutant distributions.

***Abstract:***

Pollutants resulting from industrial activity can react with sunlight to create ground-level ozone, a harmful pollutant that can exacerbate respiratory health issues such as asthma. Due to a history of heavy industrialization, residents of southeast Michigan and northern Ohio are especially susceptible to ground-level ozone. The NASA DEVELOP Southeast Michigan Health and Air Quality team, in partnership with the Michigan Department of Environment, Great Lakes, and Energy’s (EGLE) Air Quality Division and the Lake Michigan Air Directors Consortium (LADCO), investigated the effectiveness of Earth observations (EO) in monitoring pollutants that contribute to ground-level ozone. The team used the European Space Agency’s TROPOspheric Monitoring Instrument (TROPOMI) aboard Sentinel-5P, and NASA’s Ozone Monitoring Instrument (OMI) aboard Aura, to measure nitrogen dioxide (NO2), formaldehyde (HCHO), and methane (CH4) from 2019 to 2021 (May-September). The team oversampled the EO data on monthly, yearly, and 3-year time scales where possible to enhance more localized pollutant trends. NO2 can be effectively monitored from space. Specifically, TROPOMI indicated sub-city distributions on a monthly timescale. Contrastingly, the measurements of HCHO were predominately noisy, and therefore failed to show any distribution trends. Lastly, CH4 trends were identifiable yet coarse, hinting that EO monitoring in the case of CH4 is not beneficial for our partners. The end-products provide the partners with insight on the utility of EO in measuring certain ozone precursors and can be used to guide ground-level ozone reduction strategies throughout the region.

***Key Terms:***

TROPOMI, OMI, methane, nitrogen dioxide, formaldehyde, trend maps, ground-level ozone, oversampling

***National Application Areas Addressed:*** Health & Air Quality, Urban Development

***Study Location:*** southeast Michigan and northern Ohio

***Study Period:*** 2019 – 2021 (May – September)

***Community Concerns:***

* Ground-level ozone puts stress on the human respiratory system as the body is not equipped to handle triatomic oxygen. This stress could lead to the development or exacerbation of various respiratory issues and illnesses such as congestion, bronchitis, emphysema, and asthma. Respiratory issues can be detrimental to the quality of life and health of those effected. Southeast Michigan and northern Ohio show high rates of respiratory issue severity:
  + In comparison to the state of Michigan, Detroit residents experience triple the rate of asthma hospitalizations
  + Cleveland, Ohio ranked 5th on a nationwide list of cities that are deemed to be the most challenging places to live with asthma
  + 9% of residents in Lorain County, a county in northern Ohio have been diagnosed with chronic bronchitis
  + In 2019, emphysema was found to be the underlying cause of death for 489 Michigan residents
* Studies have correlated ground-level ozone levels to birth defects, namely decreased lung function and lower weight, and premature death
* Due to high levels of ground-level ozone in southeast Michigan, the region will likely not meet the EPA’s current attainment deadline. This shortcoming obligates the region to submit an implementation plan that delineates informed ozone reduction strategies.

***Project Objectives:***

* Analyze the distribution of air pollutants in southeast Michigan and northern Ohio using oversampled Aura OMI and Sentinel-5P TROPOMI data
* Generate maps that couple pollutant distribution data to point-sources and air monitoring stations
* Evaluate the utility of Earth observations (EO) in air quality monitoring using visual analysis and quantitative metrics

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **Michigan Department of Environment, Great Lakes, and Energy (EGLE), Air Quality Division** | Dr. Eduardo (Jay) Olaguer, Assistant Director of Air Quality Division | End User | No |
| **Lake Michigan Air Directors Consortium (LADCO)** | Zachary Adelman, Executive Director | End User | No |

***Decision-Making Practices & Policies:***

The mission of the Michigan Department of Environment and Great Lakes, and Energy’s (EGLE) Air Quality Division is to ensure air quality standards are met, and air quality fluctuations are monitored and communicated to the public. The Lake Michigan Air Directors Consortium (LADCO) collaborates with government agencies by providing technical support on issues related to air quality from local to regional scales. To examine the main sources of air pollution and potential ramifications of pollution-limiting programs, LADCO and EGLE mainly use intricate computer models and *in situ* data to guide air quality improvement efforts in the region.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Sentinel-5P TROPOMI** | tropospheric column NO2, total column HCHO, and total column CH4 | Sentinel-5P TROPOMI was used to create trend maps of NO2, HCHO, and CH4. |
| **Aura OMI** | tropospheric column NO2 | Aura OMI was used to create trend maps of NO2. |

***Ancillary Data***

* GIS data (point) for point source emitters in Livingston, Monroe, Oakland and Wayne counties in Michigan (provided by EGLE)
* Excel spreadsheets with location data for air quality monitoring stations in Michigan and Ohio (provided by EGLE)
* GIS data (point) for powerplant locations (Acquired from EIA)
* GIS data (point) for airport locations (Acquired from ESRI)
* GIS data (line) major roadways (Acquired from ESRI)
* GIS data (point) Michigan solid waste facilities (Acquired from EGLE)
* GIS data (point) Ohio solid waste facilities (Acquired from Ohio EPA)

***Software & Scripting:***

* IDL 8.8 – Oversampling of atmospheric data
* ENVI 5.5.2 – Visualization of oversampling outputs
* Esri ArcGIS Pro 2.8.3 – Creation of pollutant concentration maps

***End Products:***

Note: “Year” is assumed to mean May-September

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Monthly, Yearly, and 3-Year Trend Maps of NO2 with Point-Sources and Air Monitoring Location Data** | Sentinel-5P TROPOMI | NO2 trend maps provided the partners with qualitative representations of oversampled TROPOMI data paired with reference data. The partners can use the maps to evaluate the utility of monitoring NO2 using TROPOMI, and to potentially guide mitigation strategies. | N/A |
| **Yearly and 3-Year Trend Maps of HCHO with Point-Sources and Air Monitoring Location Data** | Sentinel-5P TROPOMI | HCHO trend maps provided the partners with qualitative representations of oversampled TROPOMI data paired with reference data. The partners can use the maps to evaluate the utility of monitoring HCHO using TROPOMI, and to potentially guide mitigation strategies. | N/A |
| **Yearly and 3-Year Trend Maps of CH4 with Point-Sources and Air Monitoring Location Data** | Sentinel-5P TROPOMI | CH4 trend maps provided the partners with qualitative representations of oversampled TROPOMI data paired with reference data. The partners can use the maps to evaluate the utility of monitoring CH4 using TROPOMI, and to potentially guide mitigation strategies. | N/A |
| **Yearly and 3-Year Trend Maps of NO2 with Point-Sources and Air Monitoring Location Data** | Aura OMI | NO2 trend maps provided the partners with qualitative representations of oversampled OMI data paired with reference data. The partners can use the maps to evaluate the utility of monitoring NO2 using OMI, and to potentially guide mitigation strategies. | N/A |
| **StoryMap** | N/A | Educational web tool that describes the project and results to provide public-facing communications that the end-users can circulate | N/A |

***Product Benefit to End User:***

Satellite data will allow partners to monitor the distribution of atmospheric gases in the region at consistent intervals over time. In contrast, the data types that our end-users currently employ, namely *in situ* and aerial data, only show the pollutant distribution at a specific point in time. This project explores the feasibility of capturing pollutant distributions through EO, particularly on a localized scale. The deliverables will provide the end-users with a comprehensive examination of the efficacy of EO in measuring certain pollutants, ultimately aiding the end-user in understanding the value of incorporating satellite data into their decision-making processes. The end-products can also be used to guide ground-level ozone mitigation strategies.

**References**

Asthma and Allergy Foundation of America. (2019). Asthma Captial 2019: The Most Challenging Places to Live with Asthma. <https://www.aafa.org/media/2426/aafa-2019-asthma-capitals-report.pdf>

Centers for Disease Control. (2018). Underlying Medical Conditions: Selected chronic conditions by U.S. counties, 2018. <https://covid.cdc.gov/covid-data-tracker/#underlying-med-conditions>

De Smedt, I., Pinardi, G., Vigouroux, C., Compernolle, S., Bais, A., Benavent, N., Folker, B., Ka-Lok, C., Donner, S., Kai-Uwe, E., Heldel, P., Hendrick, F., Irie, H., Kumar, V., Lamber, J-C., Bavo, L., Lerot, C., Liu, C., Loyola, D., Piters, A., Richter, A., Rivera Cardenas, C., Romahan, F., Ryan, R., Sinha, V., Theys, N., Vlietinck, J., Wagner, T., Wang, T., Yu, H., & Van Roozendael, M. (2021). Comparative assessment of TROPOMI and OMI formaldehyde observations and validation against MAX-DOAS network column measurements. *Atmospheric Chemistry and Physics*, *21*(16), 12561-12593.

Goldberg, D. L., Anenberg, S. C., Kerr, G. H., Mohegh, A., Lu, Z., & Streets, D. G. (2021). TROPOMI NO2F in the United States: A detailed look at the annual averages, weekly cycles, effects of temperature, and correlation with surface NO2 concentrations. *Earth's Future*, *9*(4), e2020EF001665. <https://doi.org/10.1029/2020EF001665>

Keller, C. A., Knowland, K. E., Duncan, B. N., Liu, J., Anderson, D. C., Das, S., Lucchesi, R. A., Lundgren, E. W., Nicely, J. M., Nielsen, E., Ott, L. E., Saunders, E., Strode, S. A., Wales, P. A., Jacob, D. J., Pawson, S. 2021). Description of the NASA GEOS composition forecast modeling system GEOS-CF v1.0. *Journal of Advances in Modeling Earth Systems*, *13*(4). <https://doi.org/10.1029/2020MS002413>

Lorente, A., Borsdorff, T., Butz, A., Hasekamp, O., Schneider, A., Wu, L., Hase, F., Kivi, R., Wunch, D., Pollard, D., Shiomi, N., Velazco, V., Roehl, C., Wennberg, P., Warneke, T., & Landgraf, J. (2021). Methane retrieved from TROPOMI: improvement of the data product and validation of the first 2 years of measurements. *Atmospheric Measurement Techniques*, *14*(1), 665-684.

Miravitlles, M., & Ribera, A. (2017). Understanding the impact of symptoms on the burden of COPD.

*Respiratory research*, *18*(1), 1-11.

State of Michigan (Ed.). (n.d.). *Leading Related Causes of Death for Underlying Deaths Due to the Emphysema Michigan Residents, 2019*. Related causes of deaths for emphysema deaths. Retrieved November 11, 2021, from <https://www.mdch.state.mi.us/osr/deaths/Related/ListTable.asp?UnderlyingNo=%2B84>.

Streets, D. G., Canty, T., Carmichael, G. R., de Foy, B., Dickerson, R. R., Duncan, B. N., Edwards, D.P., Haynes, J. A., Henze, D.K., Houyoux, M. R., Jacob, D.J., Krotkov, N. A., Lamsal, L.N., Yang, L., Zifeng, L., Martin, R.V., Pfister, G.G., Pinder, R. W., Salawitch, R.J. & Wecht, K. J. (2013). Emissions estimation from satellite retrievals: A review of current capability. *Atmospheric Environment*, *77*, 1011-1042.