Hampton Roads Health & Air Quality III

Assessing Air Quality Impacts of Construction-Related and Rush Hour Traffic in Hampton Roads

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Abstract:
This project is the third in a series of collaborations between NASA DEVELOP and the Virginia Department of Environmental Quality (DEQ) to monitor air quality in and around the Hampton Roads region. This study focuses on using Earth observations in conjunction with ground sensors, health, and traffic data to monitor trends in Nitrogen Dioxide (NO_2) surrounding the Hampton Roads Bridge Tunnel (HRBT) in relation to an ongoing expansion project. For this project two sensors were utilized: NASA's Tropospheric Emissions: Monitoring Pollution (TEMPO) and the European Space Agency's Tropospheric Monitoring Instrument (TROPOMI). TEMPO showed diurnal patterns in NO_2 levels using an oversampling technique to increase its spatial resolution while TROPOMI showed NO_2 levels before and during the expansion. Pandora ground-based sensors from the Pandonia Global Network allowed validation of TEMPO measurements, and data from the Center for Disease Control allowed spatial comparison of pollution and respiratory disease. These sources in conjunction with traffic data from the Virginia Department of Transportation allowed for map creation showing tropospheric NO_2 levels on multiple timescales before and during the HRBT expansion, a time series comparing measurements from TEMPO and Pandora, and a bivariate map comparing hotspots of tropospheric NO_2 and asthma prevalence. These project findings provide the DEQ insight into traffic patterns and their relation to NO_2 levels and public health surrounding the HRBT. Results show that long-term satellite measurements can be used alongside health data to identify high-risk communities. Additionally, TEMPO's hourly measurements can be used to track NO_2 trends at an unprecedented temporal resolution in Hampton Roads, and oversampling enables TEMPO data to display trends in tropospheric NO_2 over smaller areas than standard TEMPO data.

Key Terms:
remote sensing, TEMPO, TROPOMI, air pollution, construction, rush hour, oversampling, congestion

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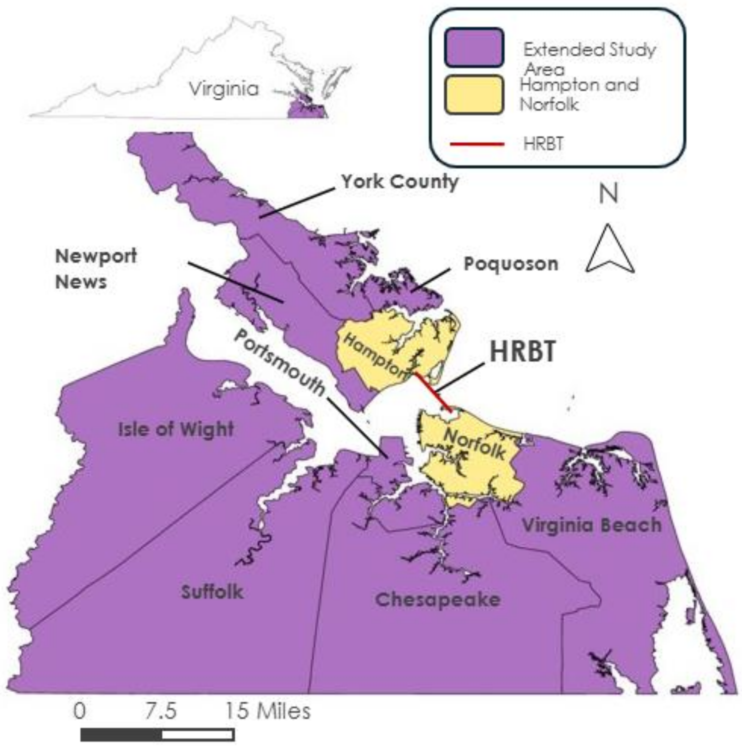
1. Introduction

1.1 Background Information

The Hampton Roads Bridge Tunnel (HRBT) is a lifeline to the diverse community of Hampton Roads, Virginia. Various traffic to and from the many local ports, universities, and military installations means the HRBT supports a wide range of industries and has become a fixture in the lives of many residents who travel, work, or live near it on a daily basis. The demands of an ever-growing population have led to an expansion project on the HRBT which started in 2020. Regular lane closures have caused additional traffic congestion in what was already a high-traffic area, causing concern over emissions from the increased volume of vehicles.



ArcGIS.(Sources: Esri, U.S. Department of Commerce, Census Bureau, U.S. Department of Commerce (DOC), National Oceanic and Atmospheric Administration (NOAA), National Ocean Service (NOS), National Geodetic Survey (NGS), NASA EarthData Search)

Figure 1. Map showing the study area and surrounding cities

Hampton Roads comprises seven major cities: Newport News, Hampton, Chesapeake, Norfolk, Virginia Beach, Portsmouth, and Suffolk. Newport News and Hampton are separated from the other five cities by the James River. Three bridges connect these two sections: the James River Bridge, the Monitor Merrimac Bridge Tunnel, and the HRBT. The study area of this project (Figure 1) is focused on the HRBT, which stretches over the James River between Hampton and Norfolk. In 2015, Hampton Roads had a population of approximately 1.66 million people, which increased to 1.78 million in 2023 (Hampton Roads TPO, 2024; Virginia Works, 2025).

Changes to traffic patterns due to the construction of the HRBT have led to increased concern about airborne pollutants in the surrounding communities. Our study focuses on the pollutant Nitrogen Dioxide (NO_2), and the relationship between increased tropospheric NO_2 levels and traffic patterns related to bridge construction. Pollutants such as NO_2 are known to cause health issues such as cancer and lung disease (American Lung Association, 2023), which may be exacerbated in this area due to increased tunnel traffic. Anthropogenic NO_2 is mostly produced through fossil fuel combustion and diesel-powered construction equipment (US EPA, 2024). NO_2 is a highly reactive gas with possible links to the development of asthma and an increased susceptibility to respiratory infections, along with a greater risk of health effects among people with pre-existing respiratory conditions (US EPA, 2024).

Virginia's Department of Environmental Quality (DEQ) has been working to track various atmospheric pollutants using air quality monitors through their Tidewater Air Monitoring Evaluation (TAME) Project since 2022. Projects such as TAME are aimed at assisting the Environmental Protection Agency (EPA) to identify places across the United States with poor air quality. The DEQ is looking to expand upon this by exploring the feasibility of using satellite data both as a stand-in for ground-based sensors in situations where they're not geographically available, and to inform potential locations for new sensors. Across many other projects, the DEQ is constantly monitoring criteria pollutants across Virginia. These pollutants, including NO_2, are known to be harmful to health and the environment, and can cause property damage (DEQ, n.d.). High concentration of NO_2 damages foliage, reduces crop yields, and can react with surfaces (Queensland Government, 2025). While the DEQ is monitoring air quality, the EPA is setting regulations using their own data and collaborations with other organizations to limit permissible levels of the pollutants.

1.2 Project Partners & Objectives

The DEQ partnered with DEVELOP to assess the feasibility of using NASA Earth observations (EOs) to further the goals of projects like TAME, which focuses on communities in Newport News and Norfolk disproportionately affected by changes in air quality. NO_2 observed by NASA's Tropospheric Emissions: Monitoring of Pollution (TEMPO) is validated with measurements from the European Space Agency (ESA) Sentinel-5 Tropospheric Monitoring Emissions (TROPOMI; Reshi, Pichuka, & Tripathi, 2024). Ground-based NO_2 column concentration measurements made by a Hampton University-based Pandora instrument from Pandonia Global Network (PGN; Rawat et. al., 2024) are used for ground-based validation of TEMPO NO_2 in the Hampton Roads region. PGN is a joint program of NASA and ESA to support calibration and validation field activities. In addition, this project is aimed at exploring the feasible application of NASA EOs data to further the DEQ's goal of effectively monitoring pollution and informing community members regarding local air quality.

1.3 Previous Projects

This study marks the third term in a series of projects collaborating with the DEQ, with each previous term exploring different applications of NASA EOs. Hampton Roads Health and Air Quality I focused on determining the feasibility of monitoring the distribution of particulate matter due to coal dust pollutants using NASA's Terra/Aqua Moderate Resolution Imaging Spectroradiometer (MODIS), Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) instrument onboard the Cloud Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) satellite and the EPA's PurpleAir sensors. The team found moderate feasibility in using satellite sensors to supplement particulate matter concentration measurements from a limited number of ground-based sensors. Hampton Roads Health and Air Quality II focused on measuring the gaseous pollutants NO_2 and Formaldehyde (HCHO) in and around Hampton Roads using TEMPO and TROPOMI in conjunction with Pandora instruments based in Hampton and Charles City, Virginia. The team found that TEMPO has moderate feasibility as a stand-in for Pandora ground sensors measuring NO_2 and HCHO. In Hampton Roads Health and Air Quality III, we aimed to build on the findings of these two projects by testing the feasibility of using remote sensing to monitor atmospheric pollution in a highly localized study area around the HRBT. These efforts are intended to assist the DEQ in their decision-making efforts regarding where to deploy air quality monitors at the HRBT and the surrounding area.

2. Methodology

2.1 Data Acquisition

To analyze atmospheric NO_2 content, we observed tropospheric vertical column measurements, measured in molecules per square centimeter (mol/cm^2), from TEMPO, TROPOMI, and Pandora instruments. These three instruments rely on spectroscopy to measure NO_2 by measuring light which has reflected off or passed through Earth's atmosphere (NASA, 2023; Rawat, 2024; Reshi, Pichuka & Tripathi, 2024). Satellite data comes in multiple levels depending on how processed it is. This project deals with Level 2 and Level 3 data. Level 2 datasets include instrument readings with derived geophysical data, while Level 3 data is mapped to a uniform space/time grid scale (Table 1; NASA, 2025). Remote Sensing Information Gateway (RSIG) is an EPA database that we used alongside NASA EarthData Search to retrieve our datasets for TEMPO and Pandora.

Table 1

List of instruments and sensors used in this project

Sensor	Parameter	Dataset	Dates	Source
TEMPO	NO_2 Tropospheric Vertical Column Concentration	TEMPO NO2 tropospheric and stratospheric columns Version 3 (PROVISIONAL), Level 2 and Level 3	9/1/2023 - 1/1/2025	RSIG, EarthDataSearch
TROPOMI	NO_2 Tropospheric Vertical Column Concentration	HAQAST Sentinel-5P TROPOMI Nitrogen Dioxide (NO2) CONUS Monthly Level 3 0.01 x 0.01 Degree Gridded Data V2.4 (HAQ_TROPOMI_NO2_CONUS_M_L3) at GES DISC	10/1/2020 - 12/31/2024	EarthDataSearch
Pandora	NO_2 Tropospheric Vertical Column Concentration	Level 2 NO_2 total vertical column amount and data quality flag (L2_rnvs)	7/1/2024 - 7/31/2024	RSIG

2.1.1 TEMPO

We heavily utilized TEMPO data for this study due to its ability to perform a scan of greater North America every hour, allowing it to track intra-daily fluctuations in pollutant levels, which is unique among similar instruments. TEMPO can do this because it is located in geostationary orbit, which leaves it perpetually above its area of interest as opposed to low Earth orbit satellites like TROPOMI, which pass over a given area once per day and thus can provide one measurement per day only (NASA, 2015). We accessed TEMPO data from EPA's RSIG database, as well as NASA's EarthData Search. We used provisional Level 2 TEMPO data to produce oversampled high-resolution gridded data. TEMPO exclusively was used for measurements after the start of the HRBT expansion, due to its earliest data being from August 2023.

2.1.2 TROPOMI

We utilized TROPOMI for its data prior to the start of the HRBT expansion, which allowed us to draw comparisons between pollutant levels before and after construction began in November 2020. Since NO_2 levels vary seasonally, we compared the average NO_2 measurements for October 2020 to October in subsequent years to look for differences. Drawing these comparisons allowed for a more informed view of the HRBT expansion's impact on local air quality. We acquired TROPOMI data from the Goddard Earth

Sciences Data and Information Services Center (GES DISC) and through NASA's EarthData Search. We sourced TROPOMI data at its provisional gridded Level 3 processing level.

2.1.3 Pandora Ground Sensors

NASA's Pandora ground sensor system served as our benchmark for our satellite instruments due to its reliability in providing ground-based tropospheric column concentration measurements in mol/cm^2, similar to its remote counterparts of TEMPO and TROPOMI. This allowed us to draw direct comparisons of remote and in-situ data at the approximate location of a given Pandora sensor. For a more reliable comparison we used the closest Pandora sensor to the HRBT, which is located at Hampton University, about 1.5 km from the eastbound entrance of the tunnel. We accessed Pandora data from 7/1/2024 to 7/31/2024 from RSIG.

2.1.5 Health Data

We utilized public health data from the Center for Disease Control (CDC) to compare levels of pollution with hotspots for certain respiratory conditions like asthma. Using health census data from the CDC through the web portal on ArcGIS, we were able to look at the percentage of people in various Hampton Roads communities affected by asthma. This data was last updated in January 2024.

2.1.7 Virginia Department of Transportation (VDOT) Data

Since this project is focused on the major roadway connecting Hampton and Norfolk, it is very important to understand the flow of traffic. This data, though not available publicly, was given to us by our contacts at VDOT. They provided us with hourly spreadsheets for both east- and west-bound traffic volume at various speeds from 2020 to 2024.

2.2 Data Processing

2.2.1 Oversampling

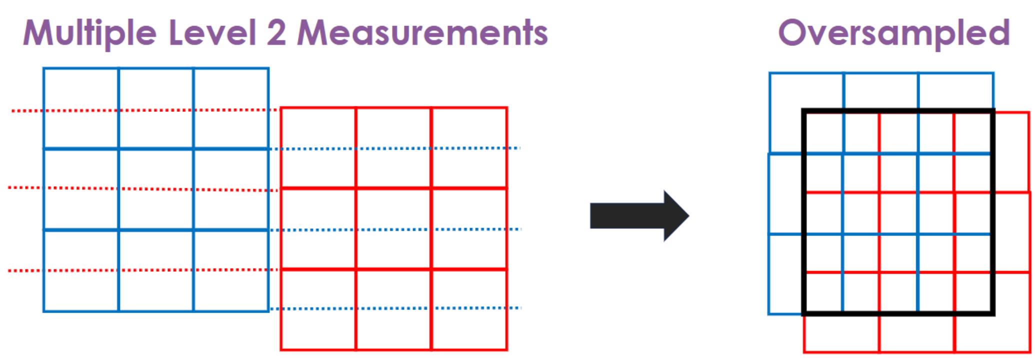


Figure 2. Simplified Oversampling Graphic

The limited size of our study area led to concern regarding TEMPO's data, and whether it could accurately portray localizations of pollutants with its native Level 2 (L2) resolution of 2.0 x 4.7 km^2, and provisional Level 3 (L3) resolution of 2.0 x 2.0 km^2. To address this concern, we implemented an oversampling technique to improve data resolution across our study area. Our technique employs fixed cell radius (point) oversampling (Sun, 2018). Fixed cell radius oversampling uses multiple L2 TEMPO scans across various timescales, builds a 1.0 x 1.0 km^2 grid, and then takes a fixed cell radius average of all data within each created grid cell.

Given the variation of sensed positions from one TEMPO scan to another, the individually sensed measurements have a certain amount of random spatial offset from each other. This offset allows overlaying multiple unaligned scans over one another. The overlaying of offset grids results in overlapping data points encompassed by the newly created grid cells, without perfect overlap of provisional grid cells. Given the offset scans are not within perfect alignment, oversampled grid cells incorporate aspects of each encompassed scan that fit within the smaller created grid cell (Figure 2; Figure A1). If scans were within perfect alignment high resolution rebuild would not be possible, as aligned native resolution grids would inhibit the ability to create an average beyond already predetermined native grid cells. Without the offset the temporal average would be more-so a general aggregate, rather than an oversampled grid rebuild. Fundamentally, you are building a new grid with the help of overlayed, non-uniformly oriented data. Trading TEMPO's high temporal resolution for an increased spatial resolution.

High scan frequency allows for complex timescale analysis. TEMPO's temporal resolution enables the production of maps and time series across various timescales including situational analysis, general long-term analysis, and indexed period analysis. With indexed period analysis a map can be created over a time interval, with a specific time-period indexed for all given data, omitting scans outside of the intended time-period, and producing a map that shows averaged NO_2 for the indexed time-period (i.e., 4pm-8pm) or throughout the longer determined time interval (i.e., 2 weeks).

An accurate fixed cell radius oversample requires multiple hourly scans. Given this, our used temporal extent is directly related to the accuracy of our created maps. Short time periods have an increased chance to lead to data artifact issues, as some scans may show abnormally high NO_2 levels that can skew the average of the fixed cell if a small number of scans are used. To best produce smoother, more accurate maps, long timescales were utilized (i.e., 2 weeks or longer). However, TEMPO's high temporal resolution allows the ability for oversampling to be done with our smaller, situational timescales, however with the caveat that artifact issues may be present. Our short timescale maps were interpreted with that caveat in mind.

2.3 Data Analysis

2.3.1 Time Series

To validate TEMPO's measurements in Hampton Roads, we tested its consistency with other instruments by comparing NO_2 tropospheric vertical column concentration measurements from TEMPO with those from Pandora in a time series. Because the Pandora sensor at Hampton University only provides data from its specific ground location, for TEMPO data acquisition for comparison we indexed oversampled TEMPO data to the corresponding 1 km x 1 km grid that encompasses the sensor, allowing for the highest spatial accuracy possible when comparing a stationary in-situ sensor to a gridded remote sensing dataset.

2.3.2 NO_2 v. Asthma Bivariate Map

To assess the correlation between atmospheric pollution and public health, we created a map identifying hotspots for both NO_2 level and asthma prevalence in the population. Our team decided that asthma was a fitting metric to compare to NO_2 levels due to its connections with NO_2 exposure (EPA, 2024). Understanding trends in health issues and pollution exposure allows organizations like the DEQ to identify sensitive areas for future ground sensor implementation, to protect both people and the environment.

2.3.3 Traffic Graphs

Our team utilized traffic volume data from VDOT to create graphs visualizing trends in traffic through the HRBT. The hourly spreadsheets for 2020-2024 got broken up into monthly sub-sheets, then as needed the hourly data was combined by day to create relevant charts. As we performed our analysis, we saw that different vehicle congestion can lead to different NO_2 patterns. We defined congestion as a high volume of cars under 35 miles per hour (mph) over a multi-hour time interval. This data allowed us to highlight peak traffic times and to identify timeframes for our maps.

2.3.4 Map Creation

To assess the effect of HRBT traffic on NO_2 levels in Hampton Roads, our team created a series of maps across a variety of timescales. To study effects of the HRBT expansion on air quality, we utilized TROPOMI to visualize monthly average NO_2 levels before and during the expansion. To analyze short-term effects of traffic congestion, our team used TEMPO to visualize NO_2 levels during individual traffic jams which were identified using VDOT traffic volume data. We also utilized TEMPO to create NO_2 maps for complex timescales. These timescales included weekdays and weekends which allowed us to see effects of weekly traffic patterns on air quality, as well as TEMPO's time-period indexed maps to analyze daily NO_2 trends of specific hourly periods, across a larger encompassing time interval.

3. Results

3.1 Analysis of Results

3.1.1 Asthma Data

At the Norfolk end of the HRBT, 11.1% of adults have asthma according to data collected in 2022 (CDC, 2020). At the Hampton end of the HRBT, 12.3% of adults diagnosed with asthma, this indicates that there is indeed an overlap between asthma prevalence and NO_2 concentration in the communities of Hampton Roads. This overlap is likely due to various causes including, but not limited to vehicle emissions of HRBT. This analysis highlights high bivariate locations as sensitive areas in which increased sensing, and air quality mitigation efforts may be productive.

3.1.2 Peak Traffic Case Studies

To observe the effects of peak traffic on NO_2 emissions, our team created maps for individual traffic backups using TEMPO data. Using VDOT traffic data, we identified a backup on 9/7/2024 at 1:00 p.m. EST. It was clearly represented as a sudden increase of number of vehicles with low speed with 0-35 MPH in Figure 3. The NO_2 concentration map from TEMPO corresponding to this backup is shown in Figure 4. Since this instance only lasted an hour and was not long enough to provide the data for an oversampled map, this map was made using provisional L3 data. There is a visible hotspot over the HRBT with a dispersal pattern over the water to the Northeast.

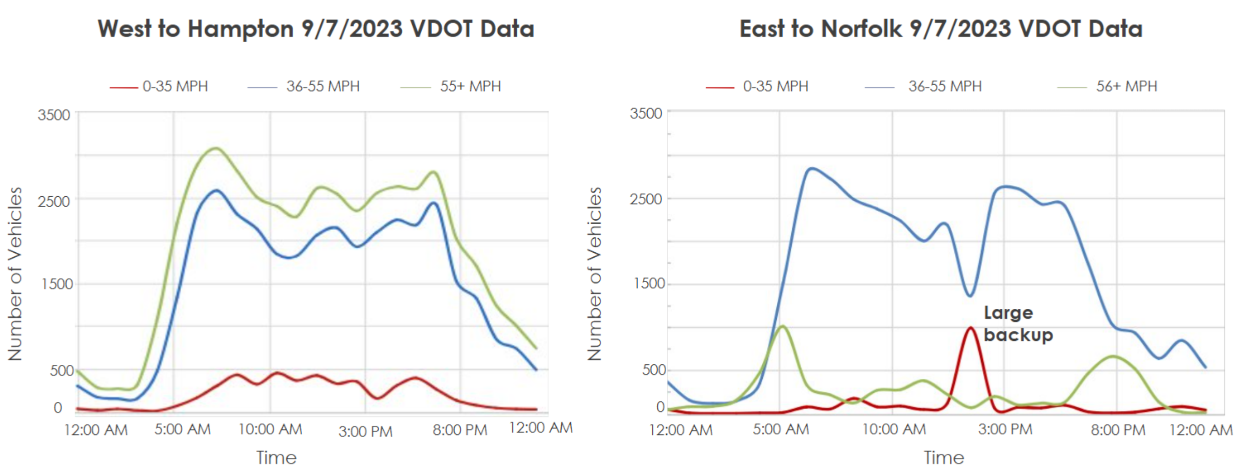
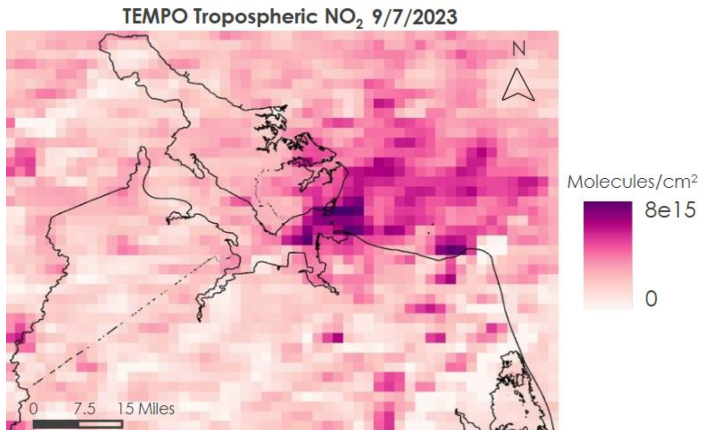


Figure 3. Westbound (left) and Eastbound (right) HRBT traffic behavior graphs for 9/7/2023

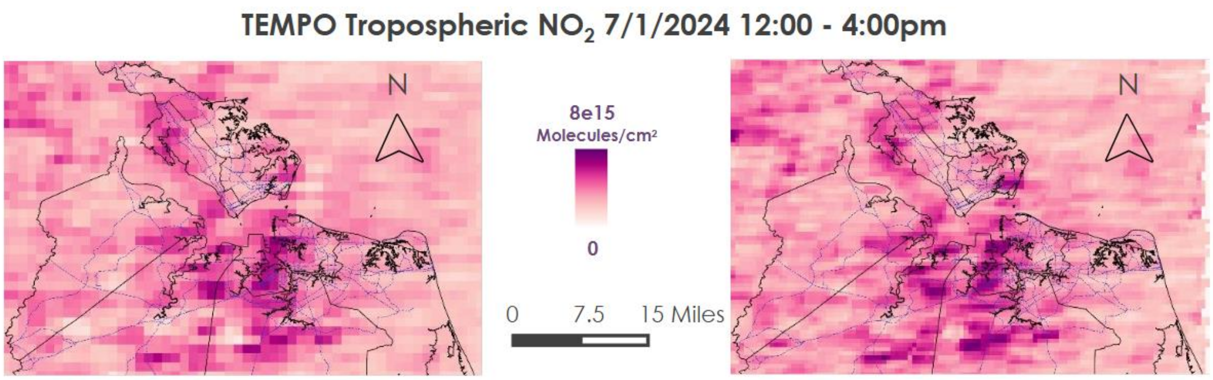


ArcGIS.(Sources: Esri, U.S. Department of Commerce, Census Bureau, DOC, NOAA, NOS, NGS, NASA EarthData Search)

Figure 4. NO_2 Tropospheric Column Map for 9/7/2023 at 1:00 pm EST with provisional L3 data.

Our team also found some longer instances of traffic congestion. One such instance occurred on 7/1/2024 and spanned from approximately 12:00 p.m. to 4:00 p.m. EST. This was long enough for us to create an oversampled map improving on the provisional resolution, from 2.0 x 2.0 km² to 1.0 x 1.0 km² (Figure 5).

Through oversampling we were able to recognize hotspots near the westbound HRBT. There is also NO_2 spread south towards Virginia Beach. This spread insinuates causation due to tunnel congestion, as well as other emitting sources in the south. These sources may include recreational activity and summer tourism traffic patterns beyond that of the HRBT.



ArcGIS.(Sources: Esri, U.S. Department of Commerce, Census Bureau, DOC, NOAA, NOS, NGS, NASA EarthData Search)

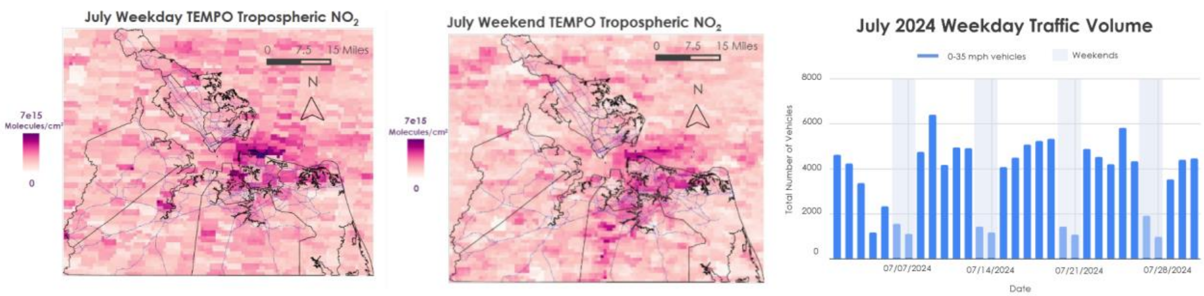
Figure 5. Provisional (left) and oversampled (right) NO_2 Tropospheric Column Maps for 7/1/2024

3.1.3 Seasonal and Monthly Case Studies

Our team looked at the seasonal changes in traffic and NO_2 levels by comparing maps and traffic graphs from June and July (Figure B1) with those from October and November (Figure B2). There is a visible difference in traffic volume through the HRBT, with higher traffic in the summer months. This may be due to Virginia Beach being a tourist hub in the summer, as well as the HRBT facilitating much of the Southern traffic to other popular locations. These traffic pattern trends may explain why there appears to be more NO_2 buildup in the summer average maps, despite winter typically seeing higher NO_2 buildup due to lower dissipation rates (Yang et al., 2024). We also produced maps for June and July separately (Figure C1; Figure C2), highlighting similar NO_2 spatial trends.

3.1.4 Weekday and Weekend Analysis

To analyze the effects of weekly traffic patterns on NO_2 emissions, we used TEMPO and VDOT data to create maps and graphs comparing weekdays to weekends in the month of July 2024. The traffic graphs show a much higher volume of slow traffic, which we defined as 0-35 miles per hour, on weekdays, likely due to commuter traffic throughout the work week. This is consistent with the weekday NO_2 column map, in which there is visible buildup on the Norfolk end of the tunnel which can likely be linked to commuter traffic through the HRBT.



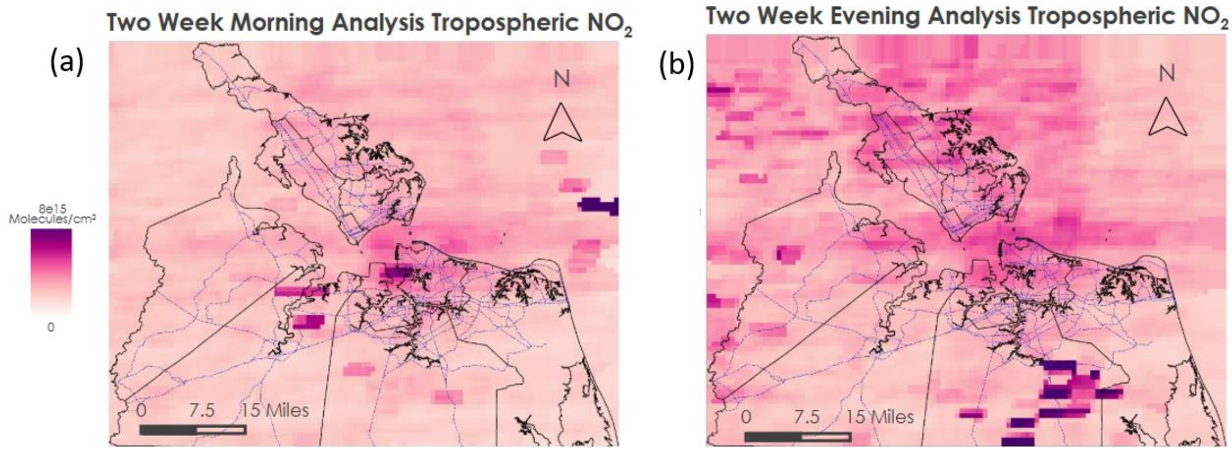
ArcGIS.(Sources: Esri, U.S. Department of Commerce, Census Bureau, DOC, NOAA, NOS, NGS, NASA EarthData Search)

Figure 6. NO_2 tropospheric column concentration maps during weekdays (left) and weekends (middle). The traffic volume data during July 2024 is plotted on the right. Weekends are shaded in gray.

Looking at the corresponding weekend analysis during July 2024 (Figure 6 middle) the buildup on the Norfolk side is still visible but not as prevalent as in the weekday map (Figure 6 left). This is likely due to the lack of commuters travelling through the tunnel, which is also shown in the traffic volume graph (Figure 6 right) which sees much lower levels of slow traffic than on weekdays. There is also a more visible buildup in the south during weekends, which may be linked to tourism and recreation in the area.

3.1.5 Specific Time Period Indexed Analysis

To identify daily patterns of NO_2 buildup, our team used VDOT data and oversampled TEMPO data to create NO_2 maps depicting morning and evening (Figure 7). Despite comparable peaks in traffic volume, the morning map appears to have the lowest NO_2 levels, followed by the evening, with the highest levels being in the midday map (Figure D2). This suggests during the Summer months at Hampton Roads, NO_2 variation is dominated by photochemical cycle (Edwards et al., 2024). The lifetime of NO_2 is only a few hours (Yang et al., 2024). The high levels of NO_2 seen at midday may be the result of lingering buildup from the morning hours combined with emissions from midday traffic. This buildup may have enough time to disperse by the evening, which could result in the lower values seen in the evening map. These maps incorporated the GIS geo-processed averaging of various oversampled maps, which resulted in high levels of data artifacts. These artifacts are likely a result of post-processing. Areas in which hotspots are concentrated do likely translate to seen build-ups in general, however with inaccurate magnitudes shown. Traffic volumes during morning rush hours, midday, and evening rush hours are included in appendix Figure D1, D2, and D3.



ArcGIS.(Sources: Esri, U.S. Department of Commerce, Census Bureau, DOC, NOAA, NOS, NGS, NASA EarthData Search)

Figure 7. NO_2 tropospheric column concentration maps for 7 a.m. to 11 a.m (a) and 4 p.m. to 8 p.m. (b) from 7/1/2024 to 7/14/2024.

3.1.6 TEMPO v. Pandora Time Series

To compare measurements between remote sensing and ground-based instruments, we constructed a time series illustrating NO_2 column concentrations recorded by the Pandora sensor at Hampton University, and by our oversampled TEMPO data for the 1.0 x 1.0 km² grid cell containing Hampton University. Our results revealed that though the two timeseries show similar trends, Pandora ground-based sensor recorded significantly higher NO_2 column concentration than TEMPO did (Figure 8). This discrepancy could be due to various factors. For example, ground sensors take measurements from a single location, whereas satellite measurements take an average value within its footprint. In this project, TEMPO data are also aggregated into 1.0 x 1.0 km² uniform oversampled grid cells. The Pandora sensor we used is located at Hampton University, which may have higher average NO_2 levels than the average for its corresponding TEMPO oversampled grid cell. Additionally, since Pandora sensors take measurements from the ground, they are closer in proximity to highly localized NO_2 sources which may stand a better chance of detection from the ground than from orbit and may have differing cloud masking impacts on data when compared to TEMPO's inverse observational perspective.

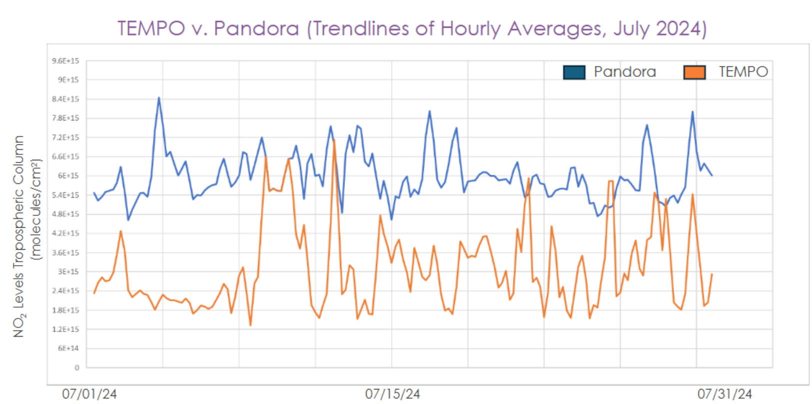
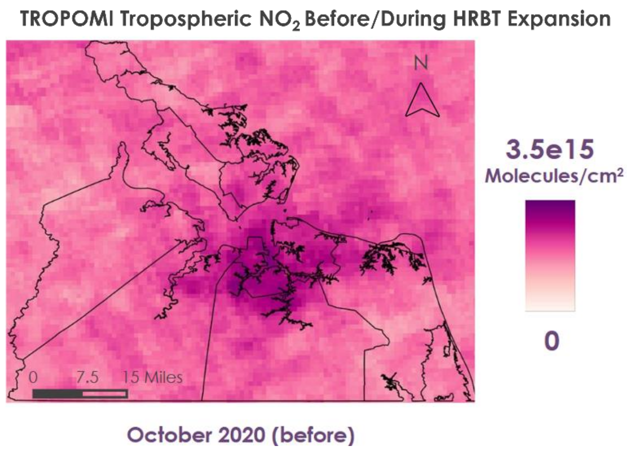


Figure 8. TEMPO vs Pandora Comparison Chart for July 2024.

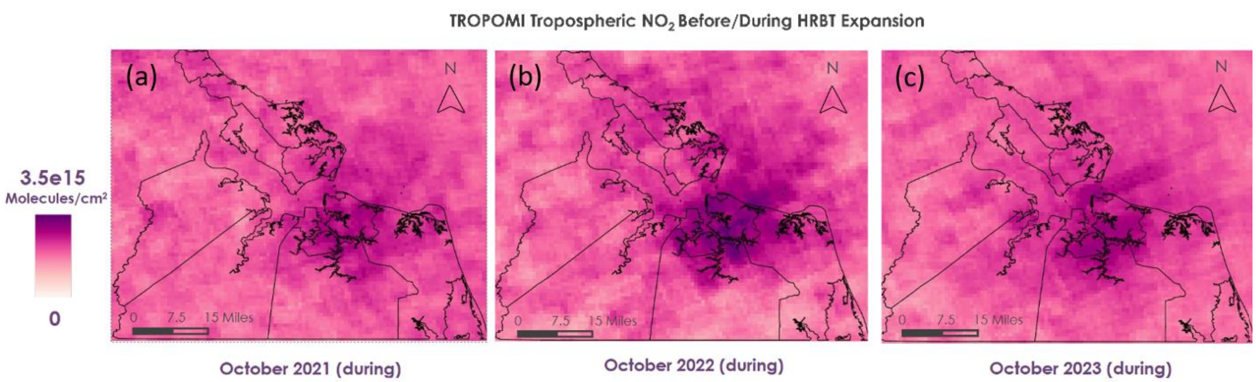
3.1.7 TROPOMI Analysis Before & During HRBT Expansion

Because the start of the HRBT expansion (November 2020) predates the launch of TEMPO (August 2023), our team utilized monthly average NO_2 column measurements from TROPOMI to compare levels before and after the project began. Since atmospheric NO_2 levels vary with the seasons, we compared the same month across multiple years. Our first comparison between October 2020 (Figure 9) and October 2021 (Figure 10 (a)) shows minimal visible change in NO_2 levels. However, moving on to 2022 (Figure 10 (b)) there is a visible increase particularly over the Norfolk area. It's worth noting that NO_2 levels can vary between years unrelated to emissions, and that an increase in pollutant levels isn't *always* the result of an increase in emissions. However, when looking at the comparison to 2023 (Figure 10 (c)), there is a visible increase in NO_2 content directly over the HRBT, which is accompanied by a streak to the Northeast, extending over the surrounding ocean.



ArcGIS.(Sources: Esri, U.S. Department of Commerce, Census Bureau, DOC, NOAA, NOS, NGS, NASA EarthData Search)

Figure 9. TROPOMI NO_2 Tropospheric Column for October 2020



ArcGIS.(Sources: Esri, U.S. Department of Commerce, Census Bureau, DOC, NOAA, NOS, NGS, NASA EarthData Search)

Figure 10. TROPOMI NO_2 Tropospheric Column for October 2021 (a), October 2022 (b) and October 2023 (c)

3.2 Errors & Uncertainties

There are multiple likely sources of NO_2 emission in our study area that are unrelated to the HRBT. Figure E1 shows the major infrastructure around HRBT in 2024. A significant example of this is ongoing construction on the 10-mile stretch of road on I-64 between Hampton and Norfolk, where the interstate is being expanded to account for the high amount of traffic seen every day, taking I-64 from four to eight lanes (VDOT, 2025). Maritime traffic is another likely source of NO_2 considering Hampton Roads is home to several ports including the Port of Virginia, the 9th busiest port in the United States as of 2023 (PANGEA, 2024). The presence of these sources makes it difficult to determine which fluctuations in local air quality were due to traffic through the HRBT.

Cloud cover is a major environmental limitation that prevents NASA EOs from collecting data, as clouds reflect the visible light that spectrometers like TEMPO, TROPOMI and Pandora need to take NO_2 measurements. Changes in temperature can affect the ability of NO_2 to build up in the atmosphere by changing the rate at which it disperses. Wind movements carry pollutants, which we were able to visualize when comparing hourly maps to wind data.

4. Conclusions

4.1 Interpretation of Results

The team found that oversampling can be used to bin Level 2 TEMPO data to a grid spacing of 1.0 x 1.0 km^2. NASA EOs can help monitor NO_2 column concentration at community scale and identify areas of concern for more ground-sensors to be installed. TEMPO is well suited to this oversampling approach given its high temporal resolution allowing more data observations than other satellite and ground observations. Based on the bivariate map (Figure F1) using health census and TROPOMI data, we found a possible positive relationship between asthma prevalence and NO_2 levels in many communities close to the study area. Though true validation would need to be expanded beyond this project, this is just an example of the potential utility of oversampled TEMPO air quality products.

4.2 Feasibility & Partner Implementation

All DEVELOP projects are, at their core, feasibility studies and this one is no different. Much of the focus of this project was aimed at exploring the capabilities of NASA Earth observations to aid our partners at the DEQ to monitor air quality at regional or community scales. We determined that using oversampling with TEMPO shows a lot of promise for obtaining detailed NO_2 measurements in community areas of comparable size to ours, especially over multi-day periods. Aside from oversampling, we determined that TEMPO shows feasibility for tracking short-term changes in NO_2 levels in Hampton Roads, as we were able to see noticeable change during peak traffic. Lastly, we found that TEMPO and TROPOMI measurements over long timeframes can be used along with health data to identify communities with increased health risks.

Our team thought of several ways our partners at the DEQ can use the information gained in this study. Firstly, they can use our findings to aid in their goal of keeping the public informed regarding air quality concerns. They can also continue to use NASA Earth Observations to identify NO_2 hotspots that may not have yet from ground sensors. Lastly, we hope these projects can help encourage community support for efforts to improve air quality for the residents of Hampton Roads.

5. Acknowledgements

Project Partners:

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- James Barringer – Office of Air Quality Monitoring, Virginia DEQ

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- Ian Turner – Virginia Department of Transportation
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This material contains modified Copernicus Sentinel data (2025), processed by ESA.

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Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration.

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6. Glossary

AQ: Air Quality
DEQ – Department of Environmental Quality

Earth observations – Satellites and sensors that collect information about the Earth's physical, chemical, and biological systems over space and time
ESA – European Space Agency
HRBT – Hampton Roads Bridge Tunnel
Level 2 data: Derived geophysical variables at the same resolution and location as L1 source data.
Level 3 data: Variables mapped on uniform space-time grid scales, usually with some completeness and consistency.
NO_2 – The chemical symbol for Nitrogen Dioxide
Oversampling – Multiple L2 scans across various timescales, builds a 1.0 x 1.0 km^2 grid, and then takes a fixed cell radius average of all data seen within each created 1km grid cell
Provisional – Level 3 data that has not gone through additional processing beyond the resolution of 2.0 x 2.0 km^2
TEMPO – Tropospheric Emissions: Monitoring of Pollution
TROPOMI – Sentinel-5 Tropospheric Monitoring Emissions

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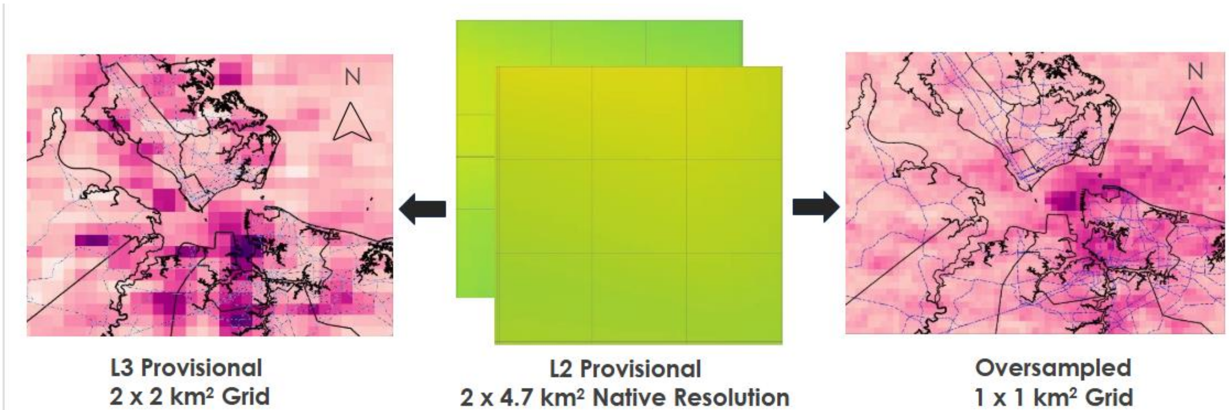
8. Appendices

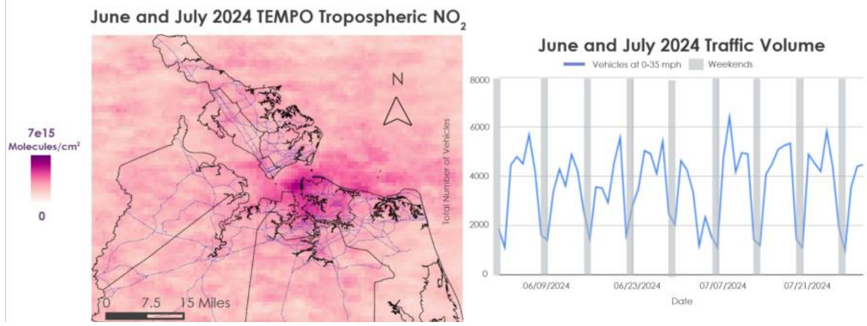
Appendix A: *Alternate Oversampling Graphic*



ArcGIS.(Sources: Esri, U.S. Department of Commerce, Census Bureau, DOC, NOAA, NOS, NGS, NASA EarthData Search)

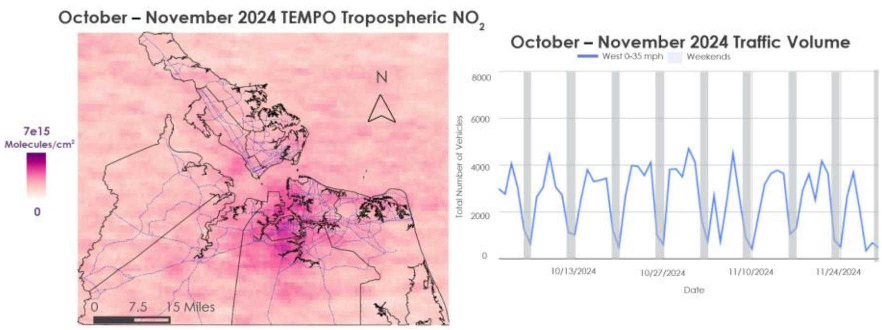
Figure A1. Oversampled Graphic Alternate, Level 3 Provisional scan of HRBT (left), Level 2 Provisional scans overlayed to show offset and grid building process (center), Oversampled Level 3 map post processing (right)

Appendix B: *Seasonal and Monthly Case Studies*



ArcGIS.(Sources: Esri, U.S. Department of Commerce, Census Bureau, DOC, NOAA, NOS, NGS, NASA EarthData Search)

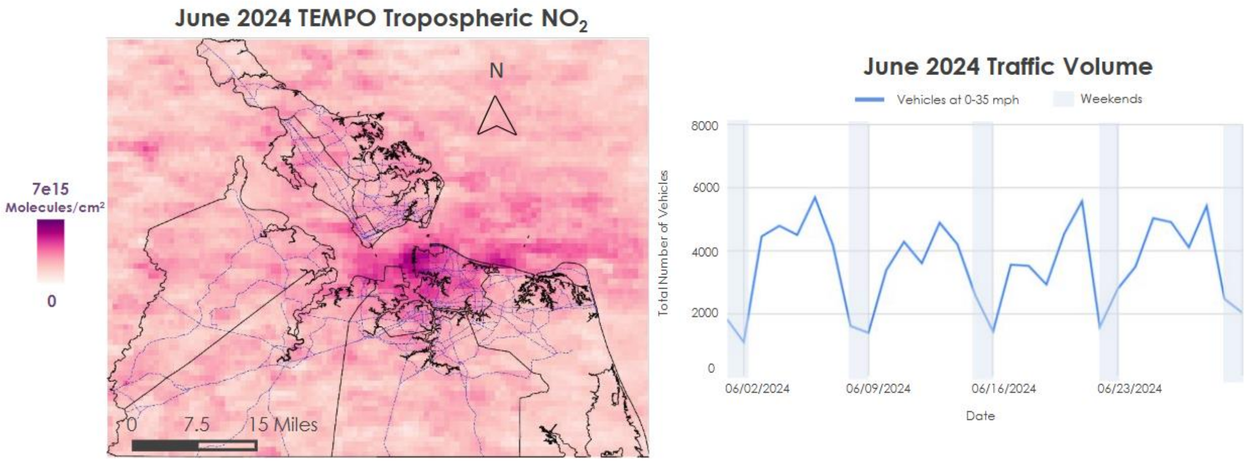
Figure B1. NO_2 Tropospheric Column Map (left) and Traffic Data Graph (right) for June/July 2024. Weekends are shaded in gray.



ArcGIS.(Sources: Esri, U.S. Department of Commerce, Census Bureau, DOC, NOAA, NOS, NGS, NASA EarthData Search)

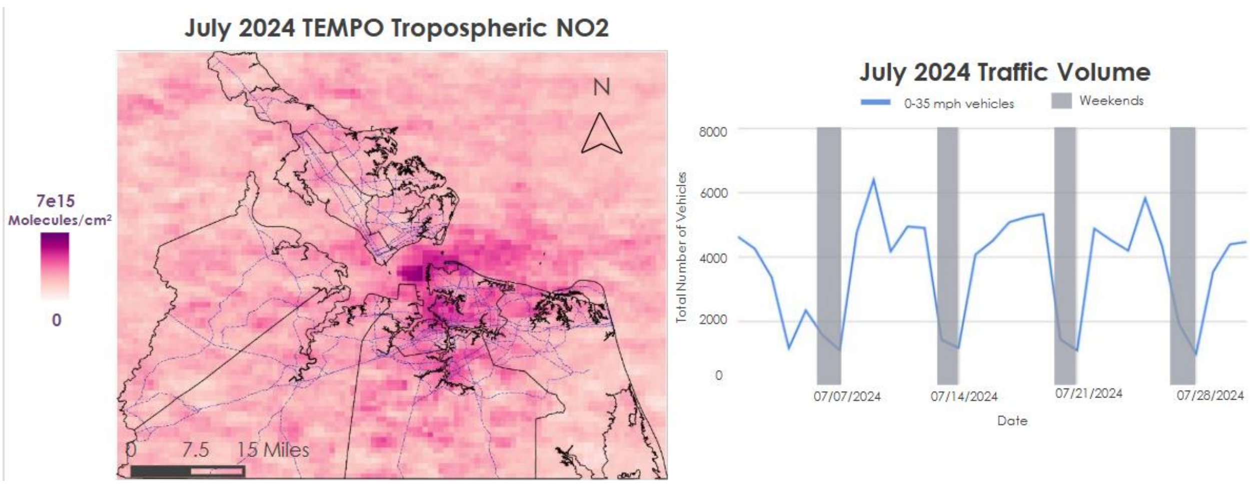
Figure B2. NO_2 Tropospheric Column Map (left) and Traffic Data Graph (right) for October/November 2024. Weekends are shaded in gray.

Appendix C: *NO_2 Tropospheric Column Maps for June & July*



ArcGIS.(Sources: Esri, U.S. Department of Commerce, Census Bureau, DOC, NOAA, NOS, NGS, NASA EarthData Search)

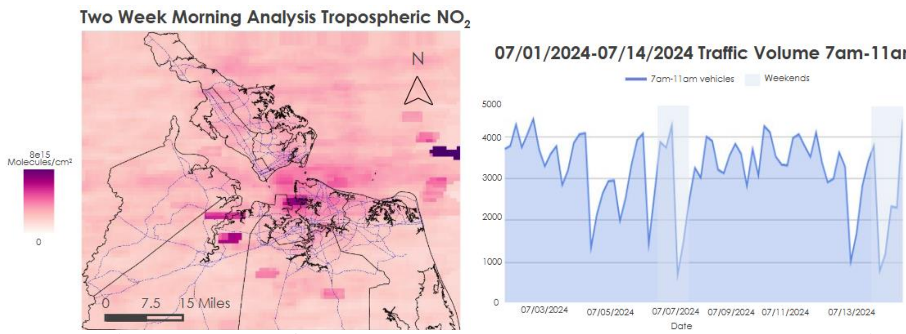
Figure C1. NO_2 Tropospheric Column Map (left) and Traffic Data Graph (right) for June 2024



ArcGIS.(Sources: Esri, U.S. Department of Commerce, Census Bureau, DOC, NOAA, NOS, NGS, NASA EarthData Search)

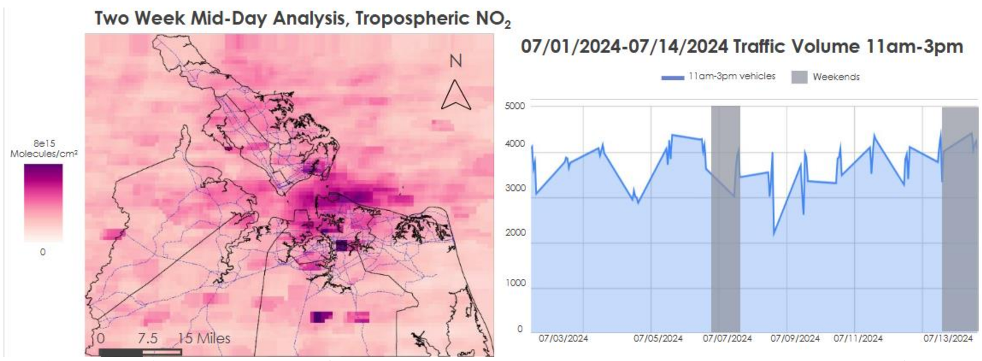
Figure C2. NO_2 Tropospheric Column Map (left) and Traffic Data Graph (right) for July 2024

Appendix D: *Traffic and Tropospheric NO_2 Correlation*



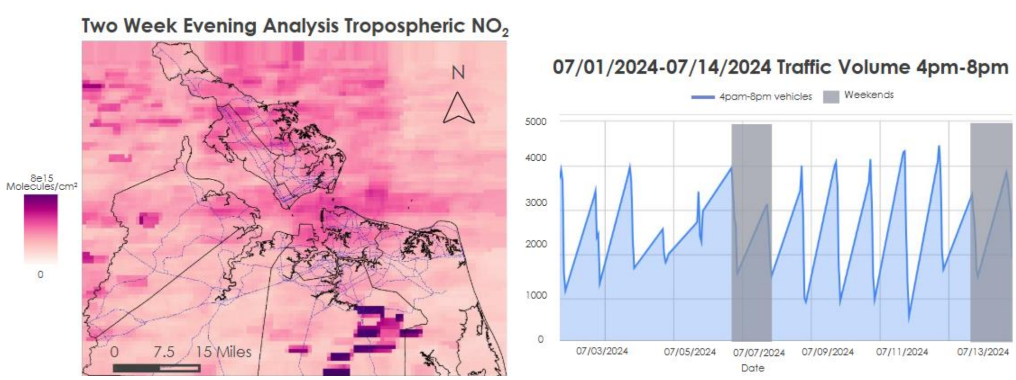
ArcGIS.(Sources: Esri, U.S. Department of Commerce, Census Bureau, DOC, NOAA, NOS, NGS, NASA EarthData Search)

Figure D1. NO_2 Tropospheric Column Map (left) and Traffic Data Graph (right) during morning rush hours from 7 a.m. to 11 a.m., 7/1/2024 - 7/14/2024, the gray shaded boxes show weekends.



ArcGIS.(Sources: Esri, U.S. Department of Commerce, Census Bureau, DOC, NOAA, NOS, NGS, NASA EarthData Search)

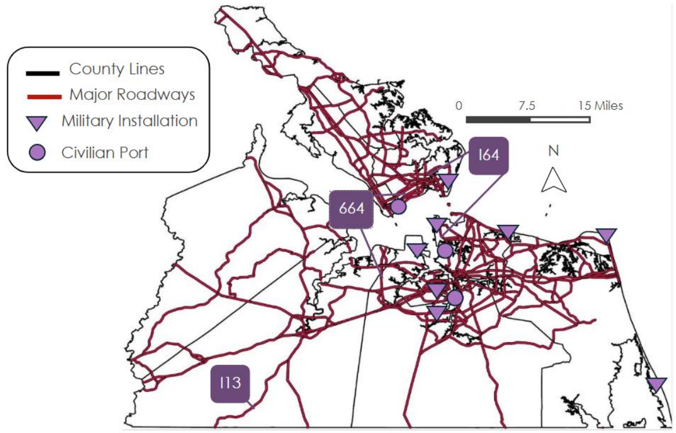
Figure D2. NO_2 Tropospheric Column Map (left) and Traffic Data Graph (right) during midday from 11a.m. to 3 p.m., 7/1/2024 - 7/14/2024.



ArcGIS.(Sources: Esri, U.S. Department of Commerce, Census Bureau, DOC, NOAA, NOS, NGS, NASA EarthData Search)

Figure D3. NO_2 Tropospheric Column Map (left) and Traffic Data Graph (right) during evening rush hours from 4 p.m. to 8 p.m., 7/1/2024 - 7/14/2024, the gray shaded boxes show weekends.

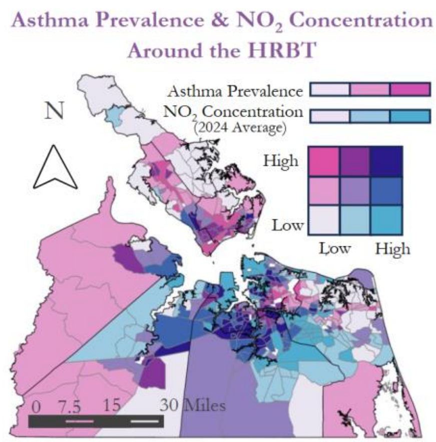
Appendix E: *Hampton Roads Infrastructure*



ArcGIS.(Sources: Esri, U.S. Department of Commerce, Census Bureau, DOC, NOAA, NOS, NGS, NASA EarthData Search)

Figure E1. Major Infrastructure in Hampton Roads in 2024.

Appendix F: *Asthma Bivariate Map*



ArcGIS.(Sources: Esri, U.S. Department of Commerce, Census Bureau, DOC, NOAA, NOS, NGS, NASA EarthData Search)

Figure F1. Map overlaying asthma prevalence and NO_2 concentration across Hampton Roads.