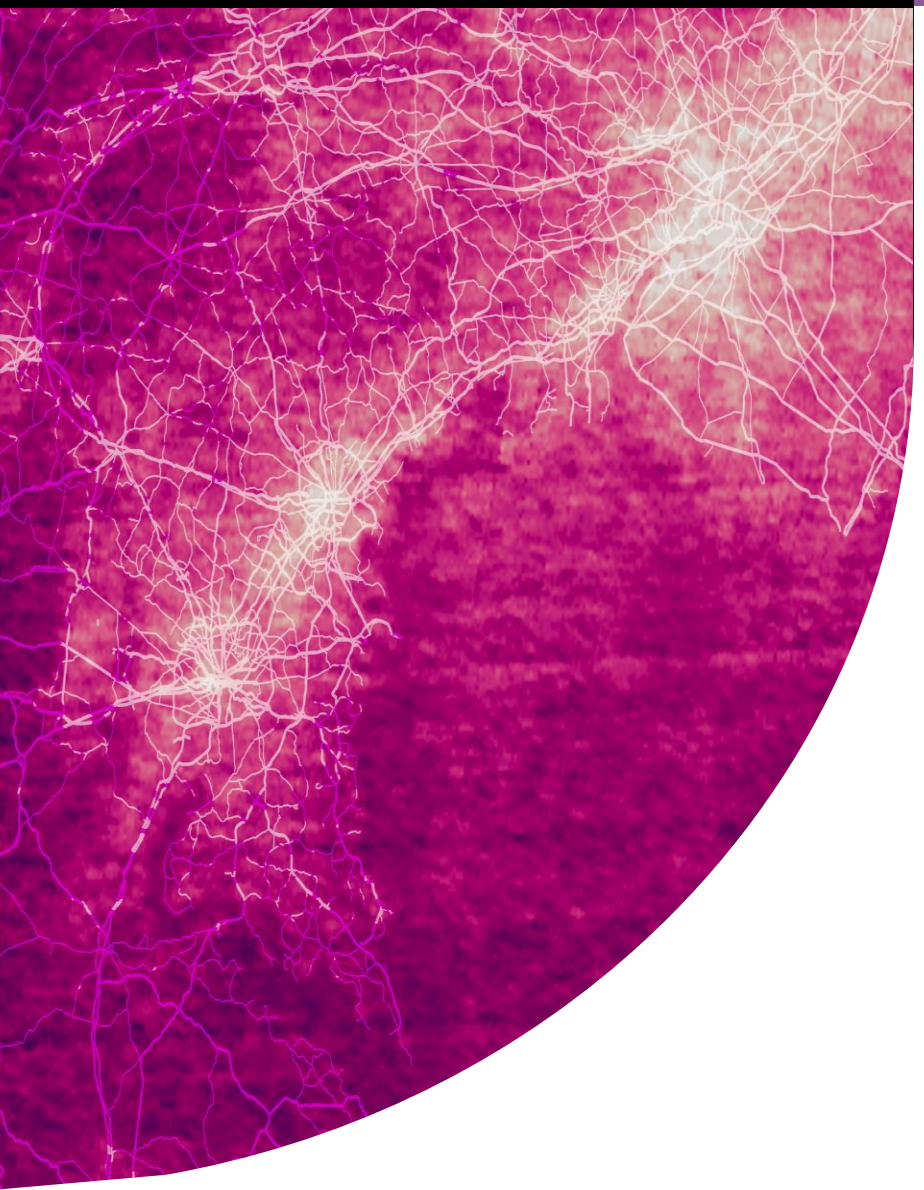
National Aeronautics and Space Administration



Hampton Roads Health & Air Quality III

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

Joseph Horan, Stormi Nichols, Alexia Stechele, David Wilcox (Analytical Mechanics Associates)

Virginia – Langley | Spring 2025

Meet the Team

Joseph Horan
(Project Lead)

Alexia Stechele

David Wilcox

Stormi Nichols

Partner

Virginia Department of Environmental Quality (DEQ)

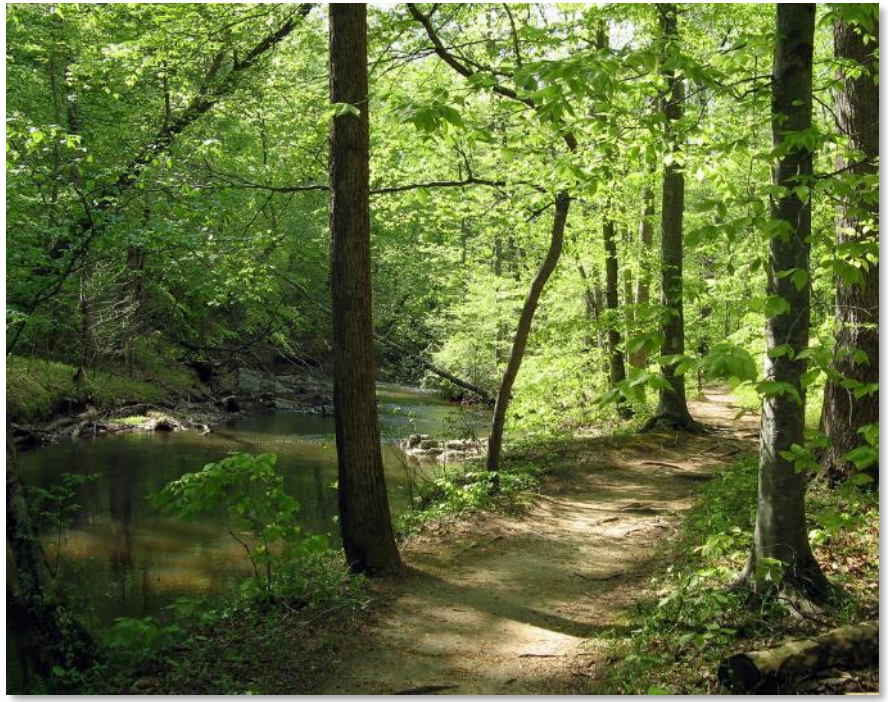


Image Credits: Diana Robinson, PickPick, ForestWander

"DEQ carries out its mission to protect and improve the environment for the health, well-being and quality of life of all Virginians"

-Virginia Department of Environmental Quality

General Background

Image Credit: VDOT

The Hampton Roads Bridge Tunnel (HRBT) began an expansion project in 2020 and is expected to continue until 2027

The HRBT normally experiences large-scale traffic backups

Image Credit: VDOT

Community Concerns

Vehicle exhaust is linked to multiple atmospheric pollutants, including Nitrogen Dioxide (NO_2)

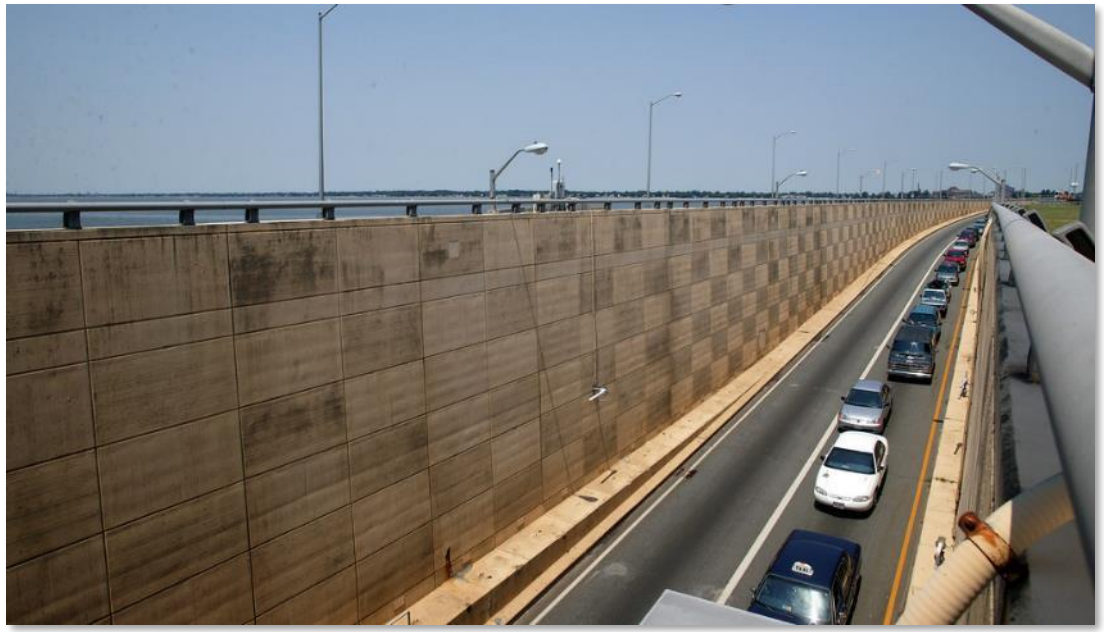


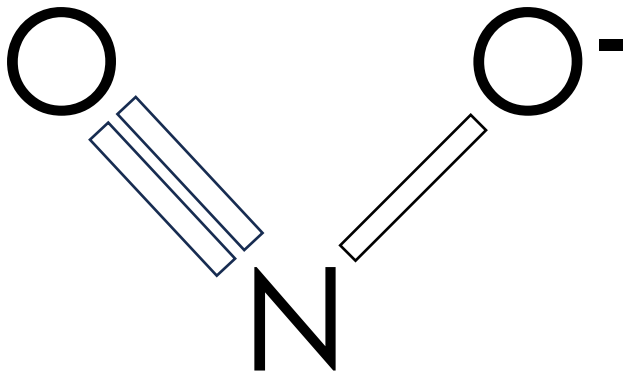
Image Credit: Ben Schumin

Image Credit: VDOT

NO_2 has been linked to a variety of adverse health effects

Pollutant of Interest

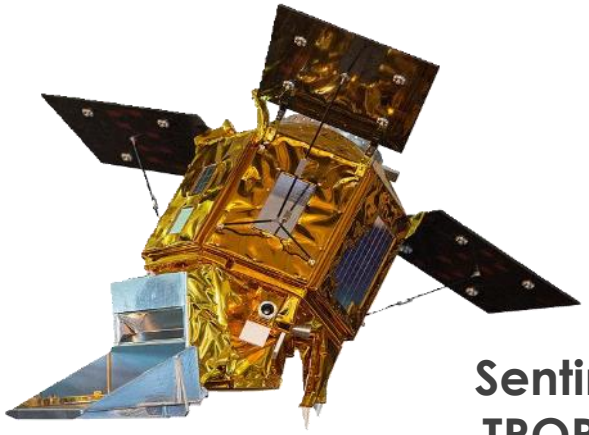
NO_2 is a highly reactive gas. Its presence in the atmosphere is mainly attributed to emissions from **vehicles, power plants, and other machinery**



<u>NO_2 exposure has been linked to the following:</u>

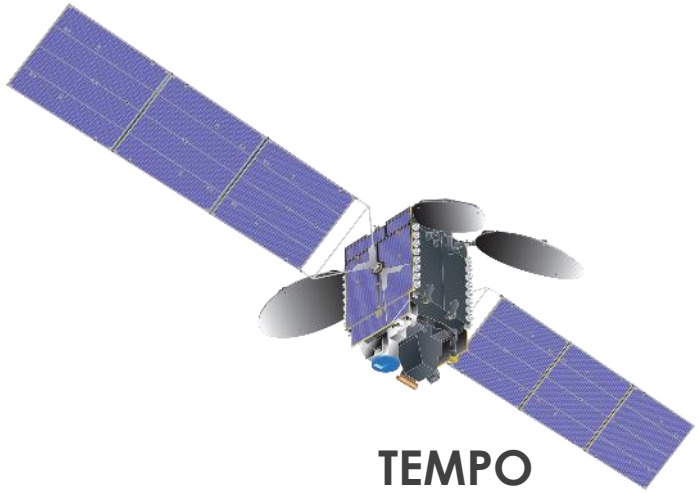
- Damage to lung cells & cell membranes
- Increased risk of respiratory disease
- Increased susceptibility to respiratory infection
- Contribution to asthma development

Earth Observations



Sentinel-5
TROPOMI

TROPOspheric
Monitoring
Instrument



TEMPO

Troposheric
Emissions:
Monitoring
POllution

Image Credit: SkywalkerPL, NASA

Pandora System

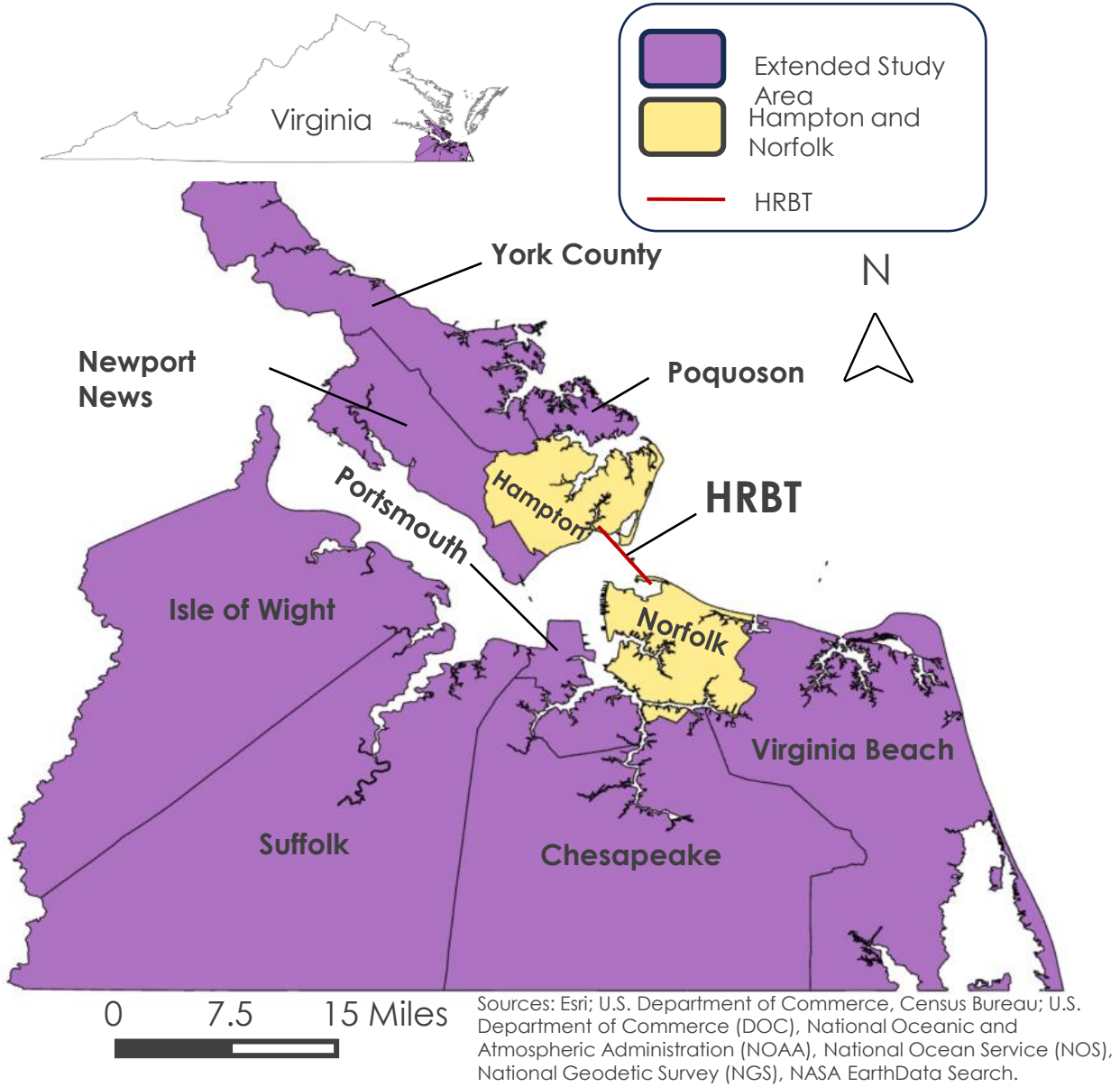
Image Credit: NASA

Pandora is a system of ground-based spectrometers that monitor air quality

Compare measurements from Pandora sensors to TEMPO and TROPOMI data

Study Area & Period

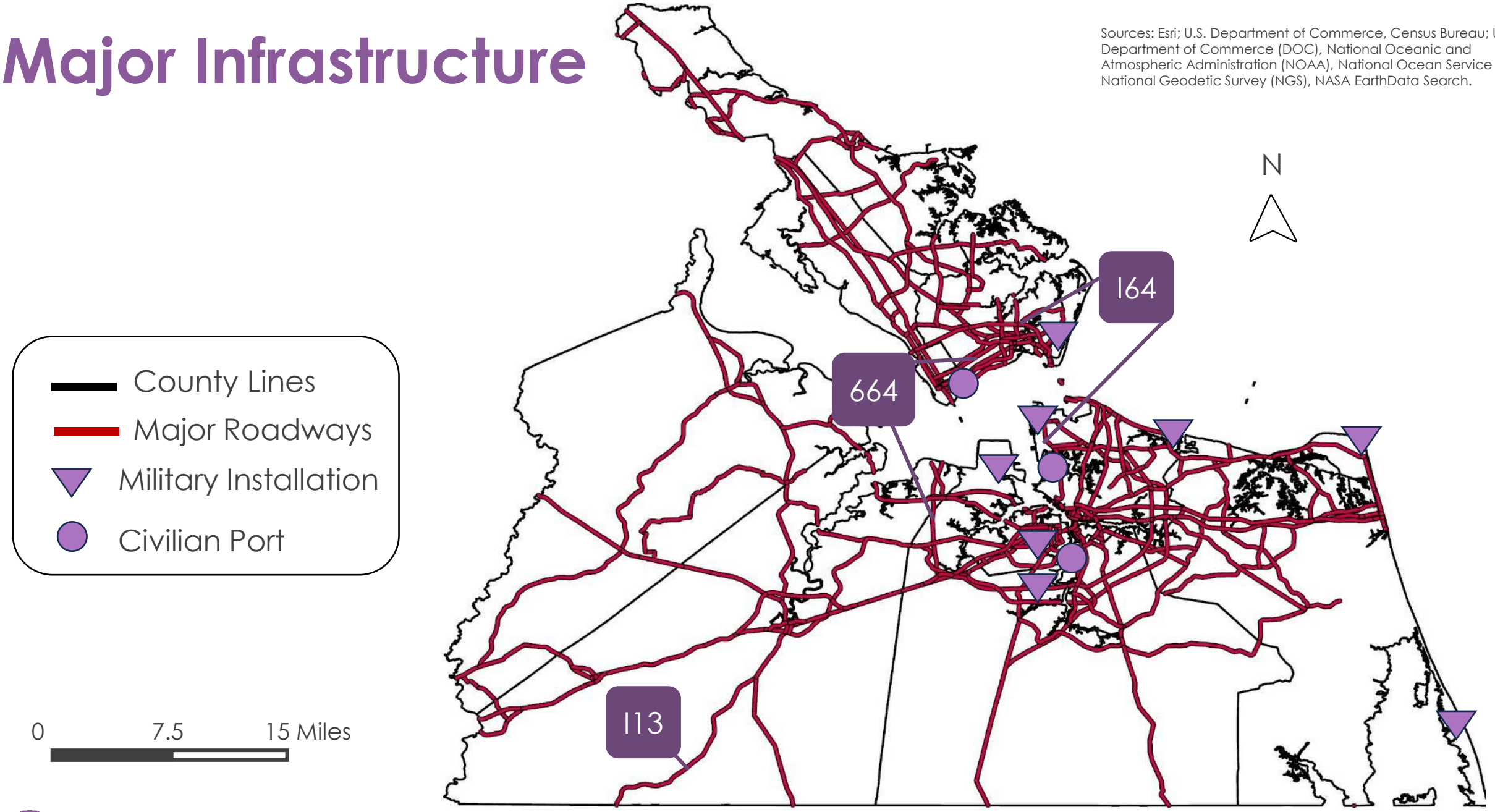
- **Study area:** Focusing on the HRBT and the two connected cities of Hampton and Norfolk, with an extended study area of surrounding cities
- **Study period:** August 2023 - January 2025



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.

Major Infrastructure

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.



Project Objectives

Analyze the feasibility of monitoring NO_2 using NASA Earth Observations

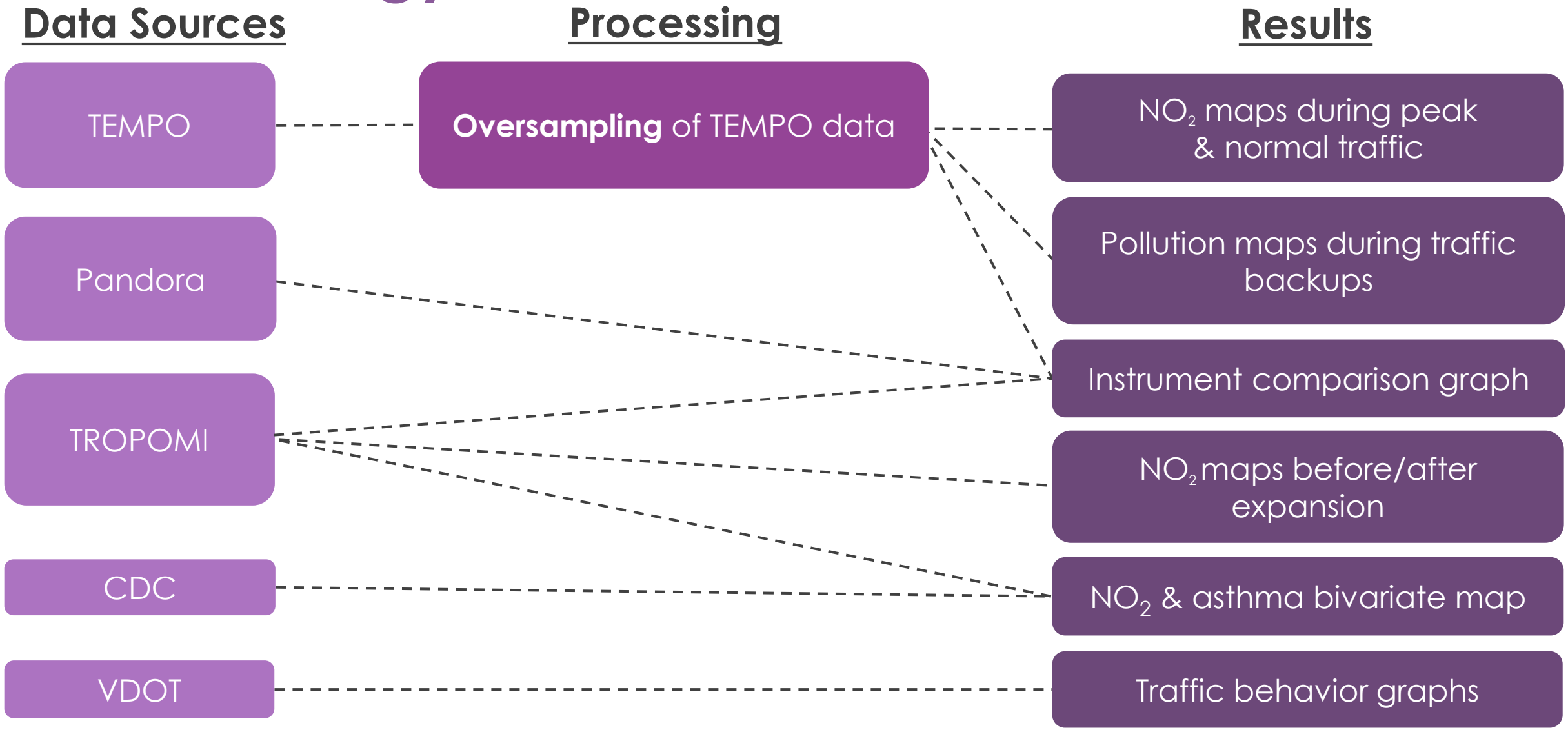
Assess feasibility of oversampling to increase resolution in the target area

Identify trends in NO_2 vertical columns before & during traffic congestion

Measure NO_2 vertical columns before and after the start of the HRBT expansion

Compare measurements to local health data and identify vulnerable areas

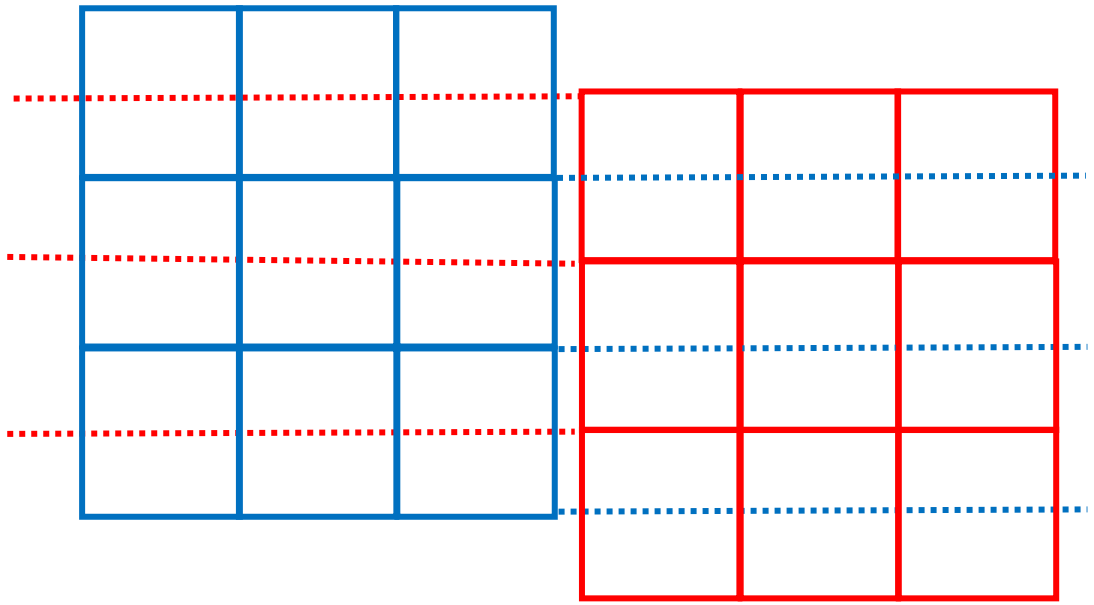
Methodology – Data Sources & Products



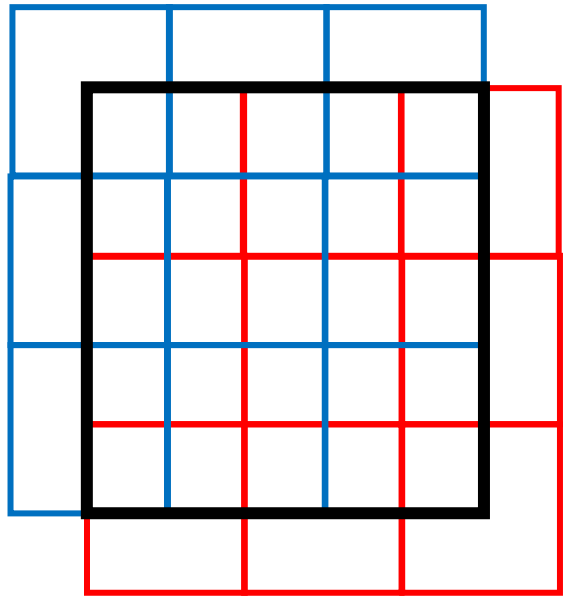
Methodology – TEMPO Oversampling

Oversampling provides greater spatial information for analysis over the study area

Multiple Level 2 Measurements



Oversampled

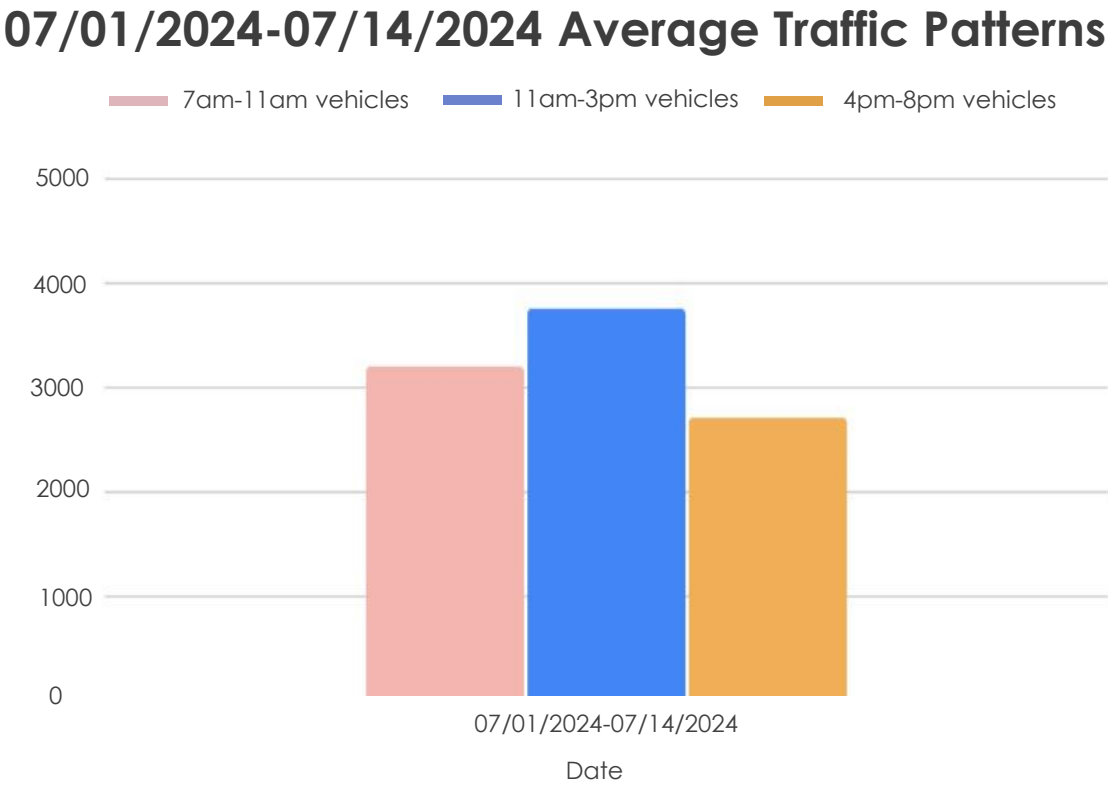


Level 2 Provisional Data: granules with native resolution (2 x 4.7 km^2)
Oversampled: Uses multiple Level 2 granules to create a higher resolution grid (1 x 1 km^2)

VDOT & Traffic Data

The Virginia Department of Transportation (VDOT) keeps records of traffic through the HRBT

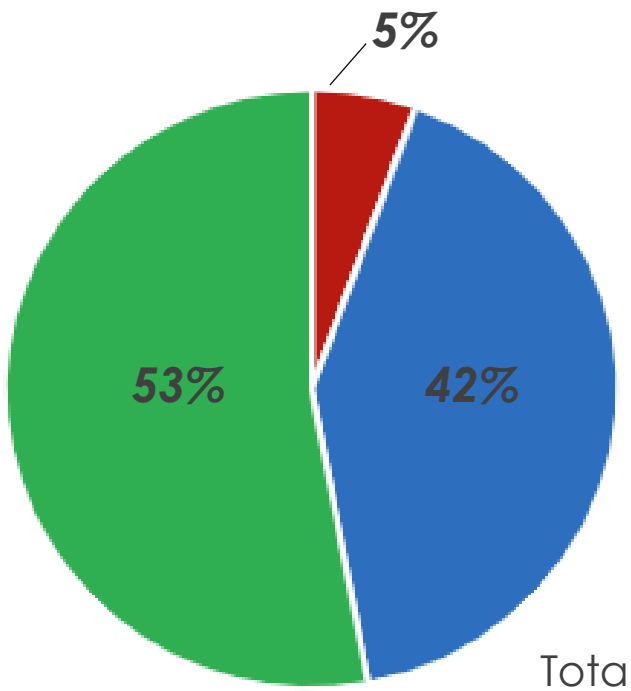
These records include vehicle speed and volume, which allowed our team to identify traffic patterns for mapping and analysis



11am-3pm has most consistent traffic

Total Month Vehicle Volume

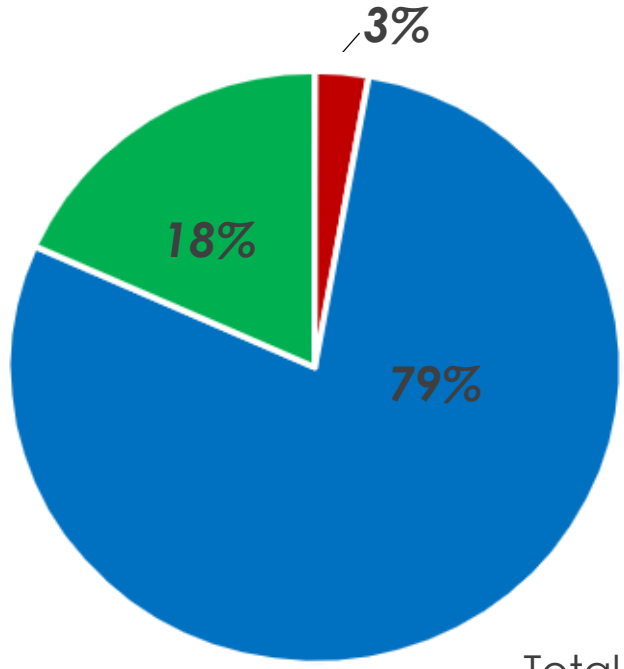
West to Hampton September 2023 VDOT Data



Total vehicles:
1,230,032

Vehicles at 0-30 MPH
Vehicles at 31-50 MPH
Vehicles at 51+ MPH

East to Norfolk September 2023 VDOT Data

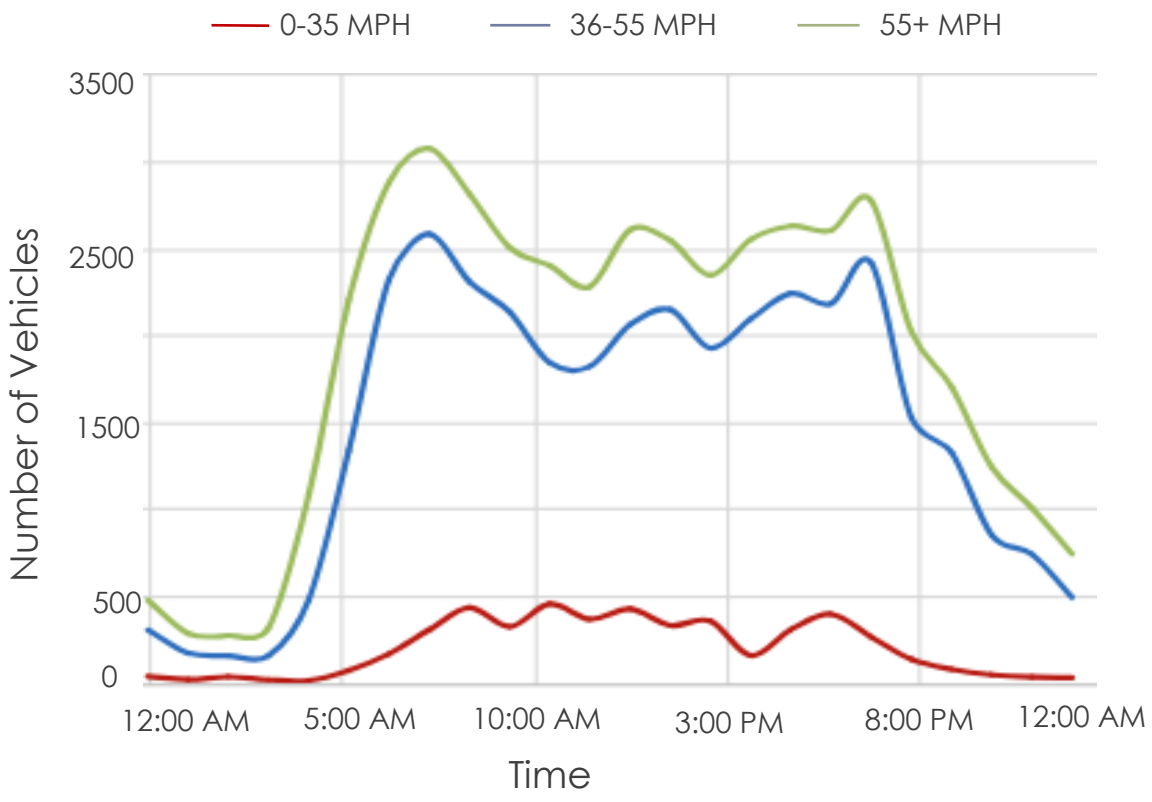


Total vehicles:
1,256,323

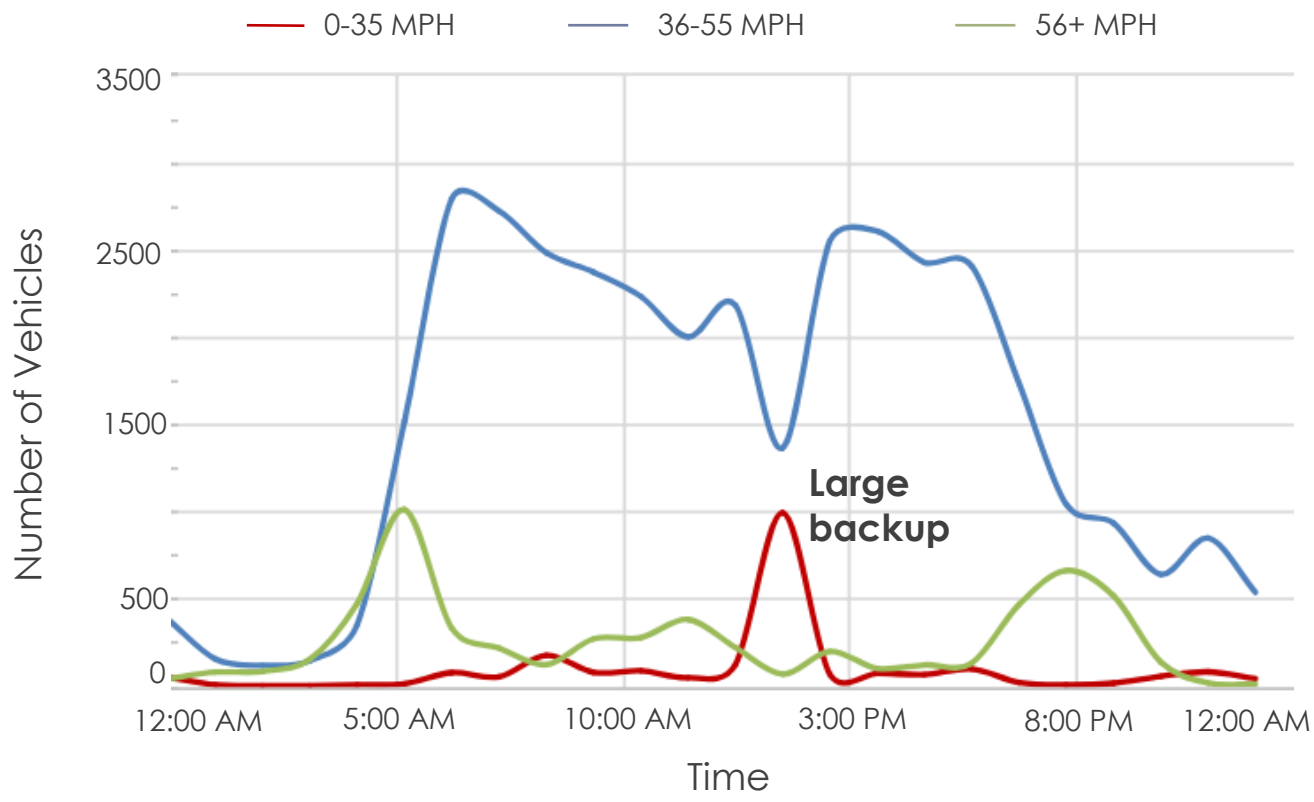
Vehicles at 0-30 MPH
Vehicles at 31-50 MPH
Vehicles at 51+ MPH

Traffic Volume Charts

West to Hampton 9/7/2023 VDOT Data

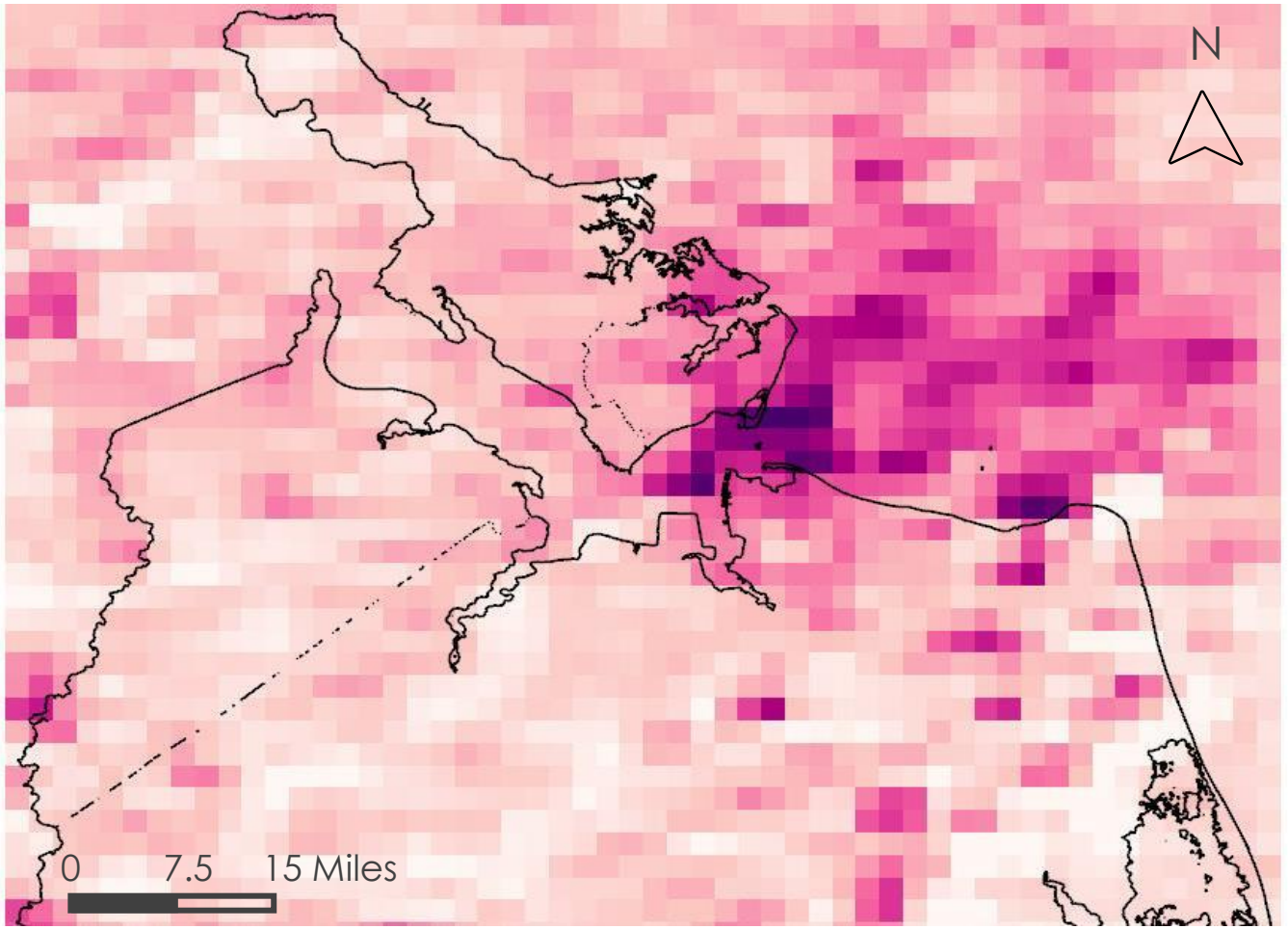


East to Norfolk 9/7/2023 VDOT Data



Provisional L3 Individual Traffic Backup

TEMPO Tropospheric NO_2 9/7/2023



Molecules/cm^2

8e15

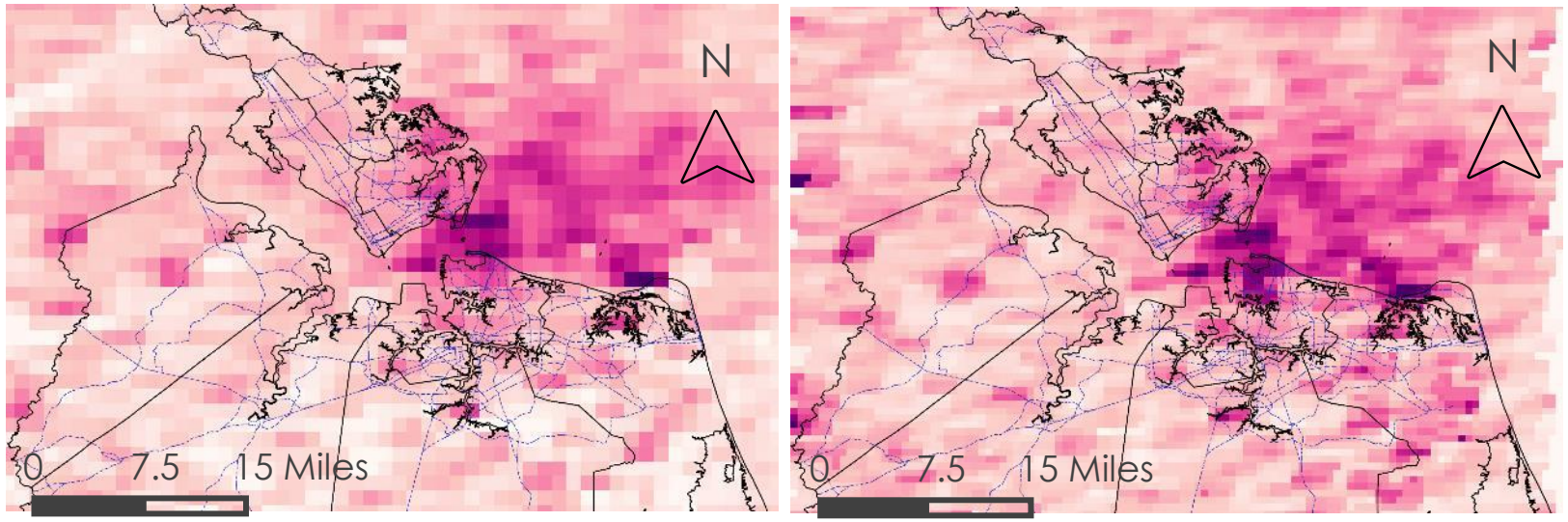
0

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.

TEMPO's hourly measurements allow the team to look at individual events like traffic backups and their effects on local NO_2 vertical columns

Oversampled Individual Traffic Backup

TEMPO Tropospheric NO_2 9/07/2024 12:00 - 2:00pm

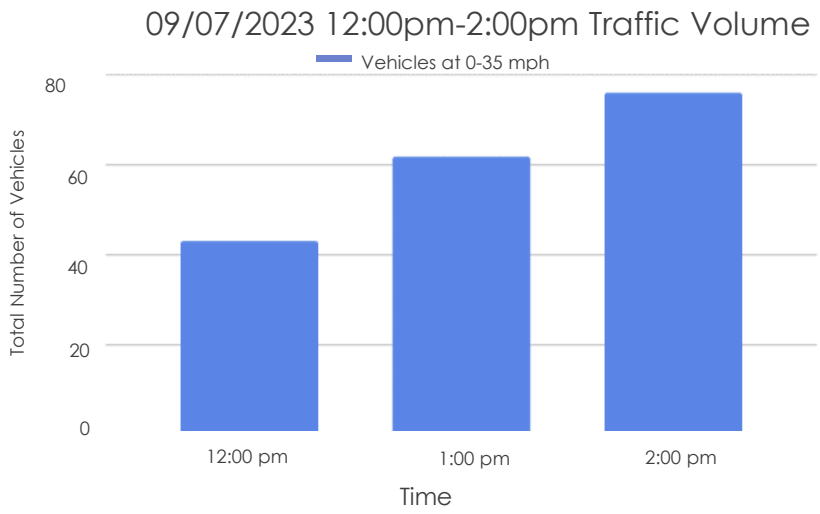


Provisional Level 3
(2:4.7km)

8e15
Molecules/cm²

0

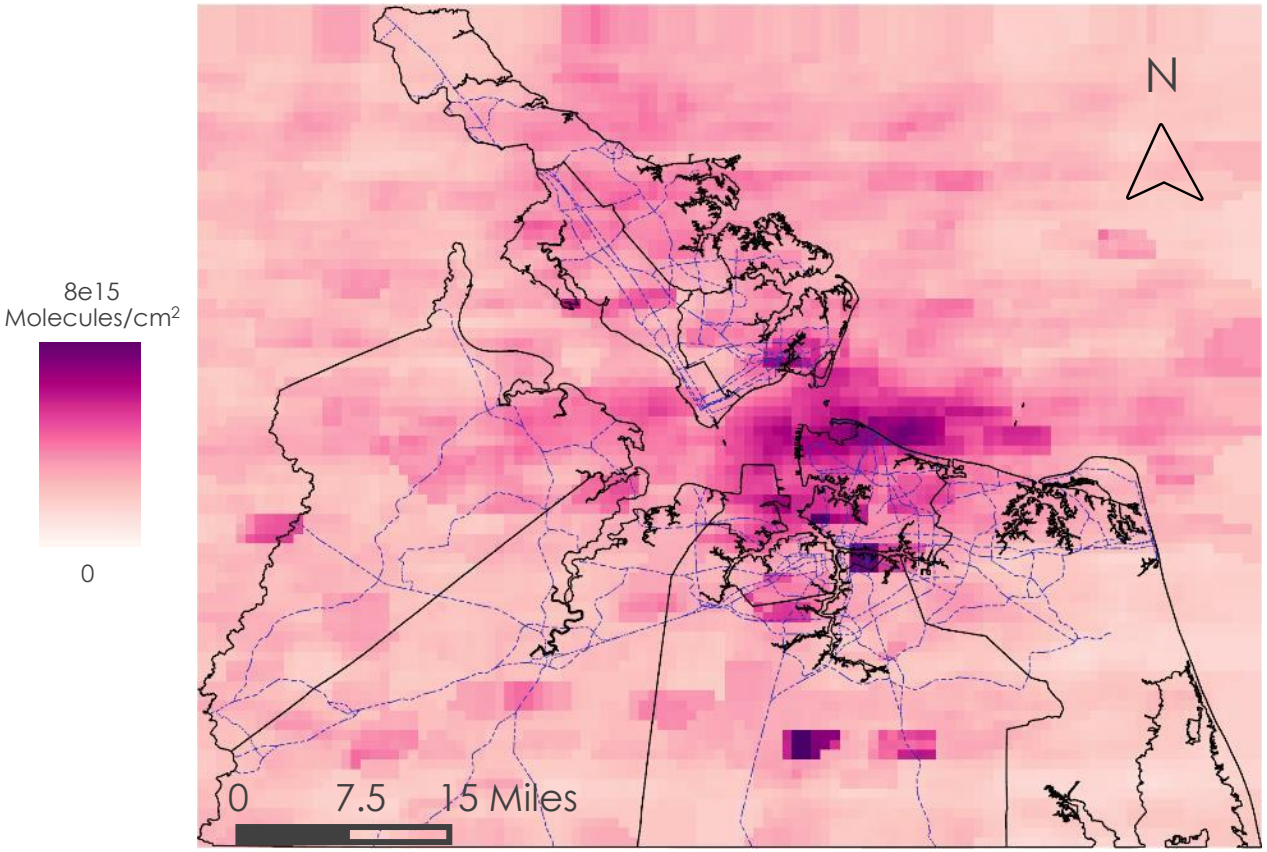
Oversampled
(1:1km)



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.

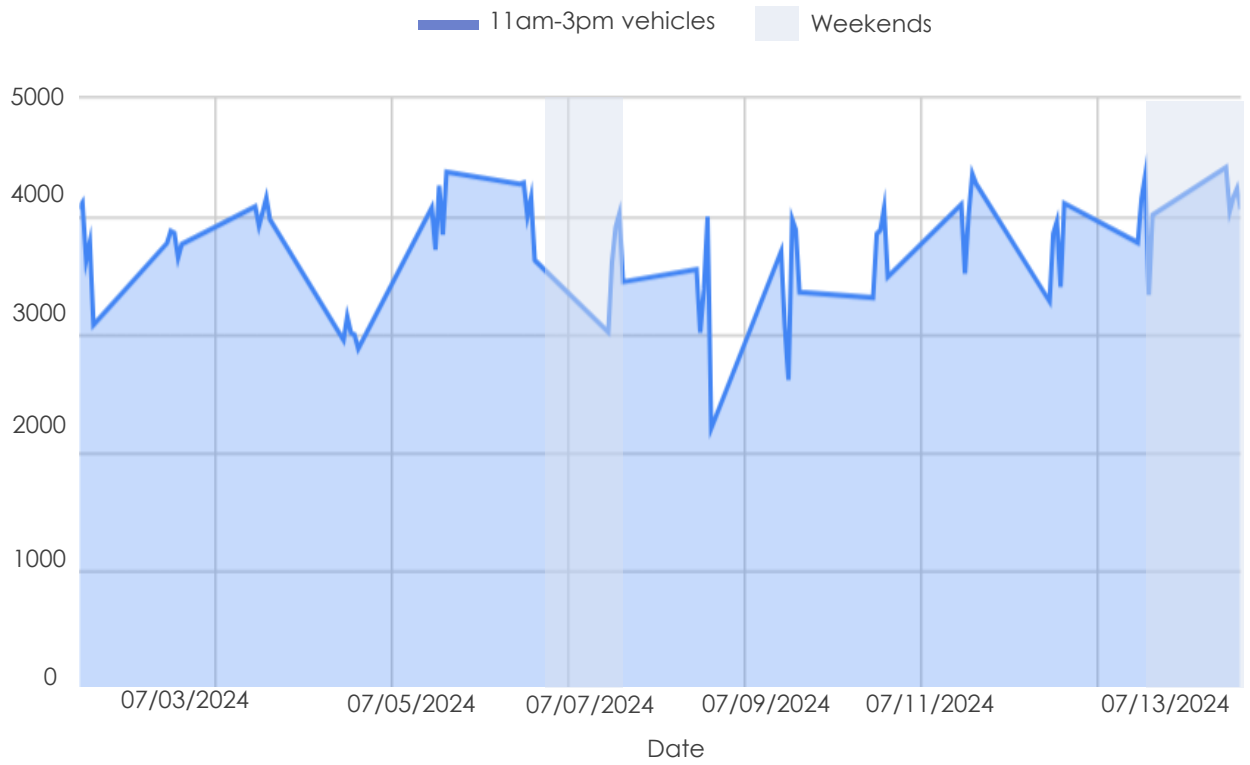
Oversampled TEMPO – Two Week Mid-Day Analysis

TEMPO Tropospheric NO_2



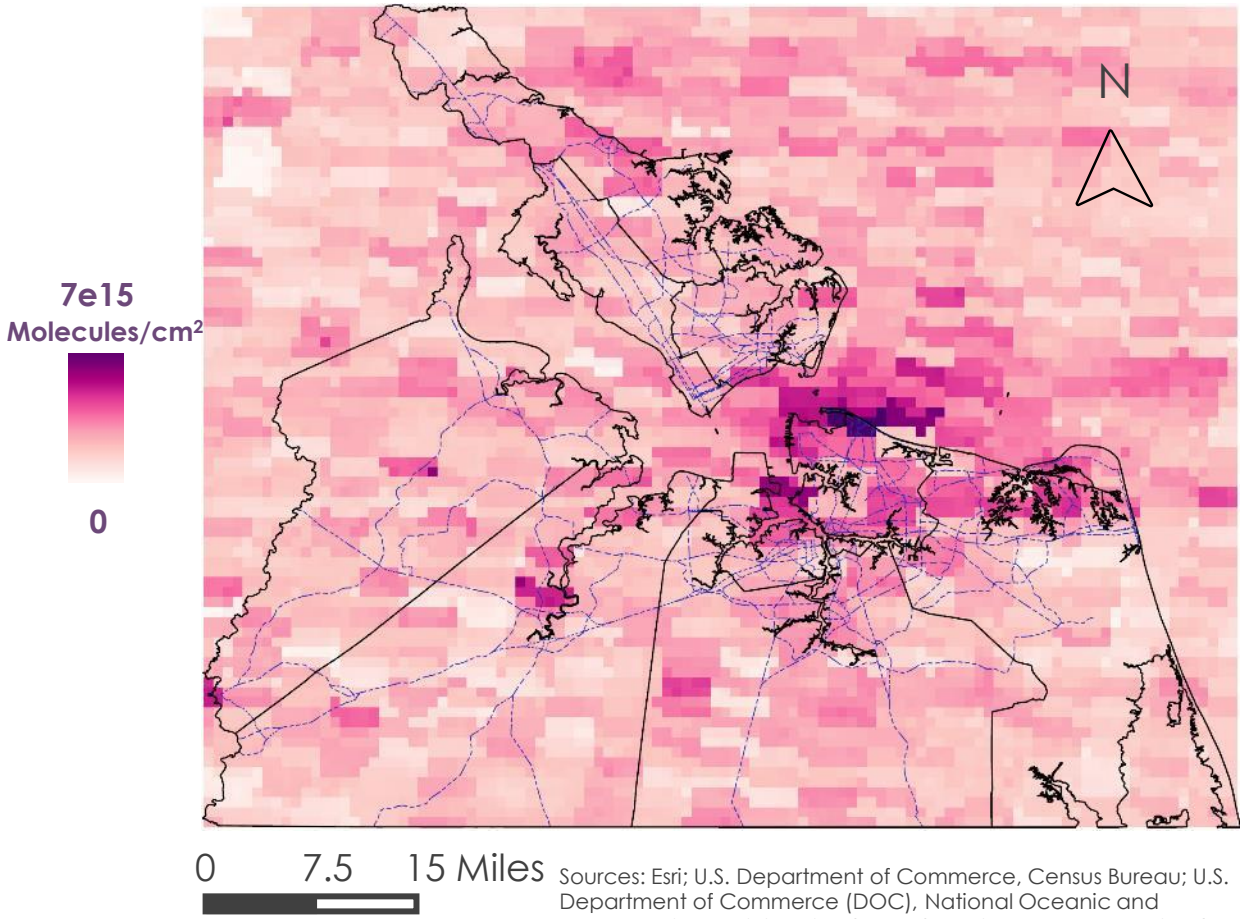
Sources: Esri; U.S. Department of Commerce, Census Bureau; U.S. Department of Commerce (DOC), National Oceanic and Atmospheric Administration (NOAA), National Ocean Service (NOS), National Geodetic Survey (NGS), NASA EarthData Search.

07/01/2024-07/14/2024 Traffic Volume 11am-3pm



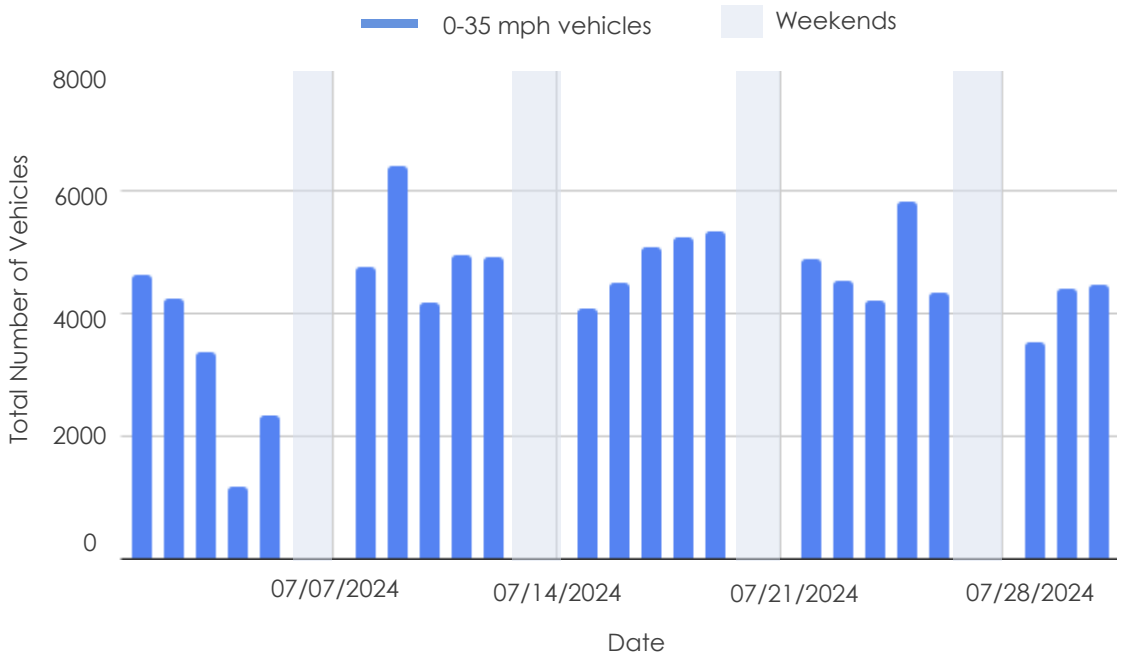
Oversampled TEMPO – Weekday Analysis

July Weekday TEMPO Tropospheric NO_2



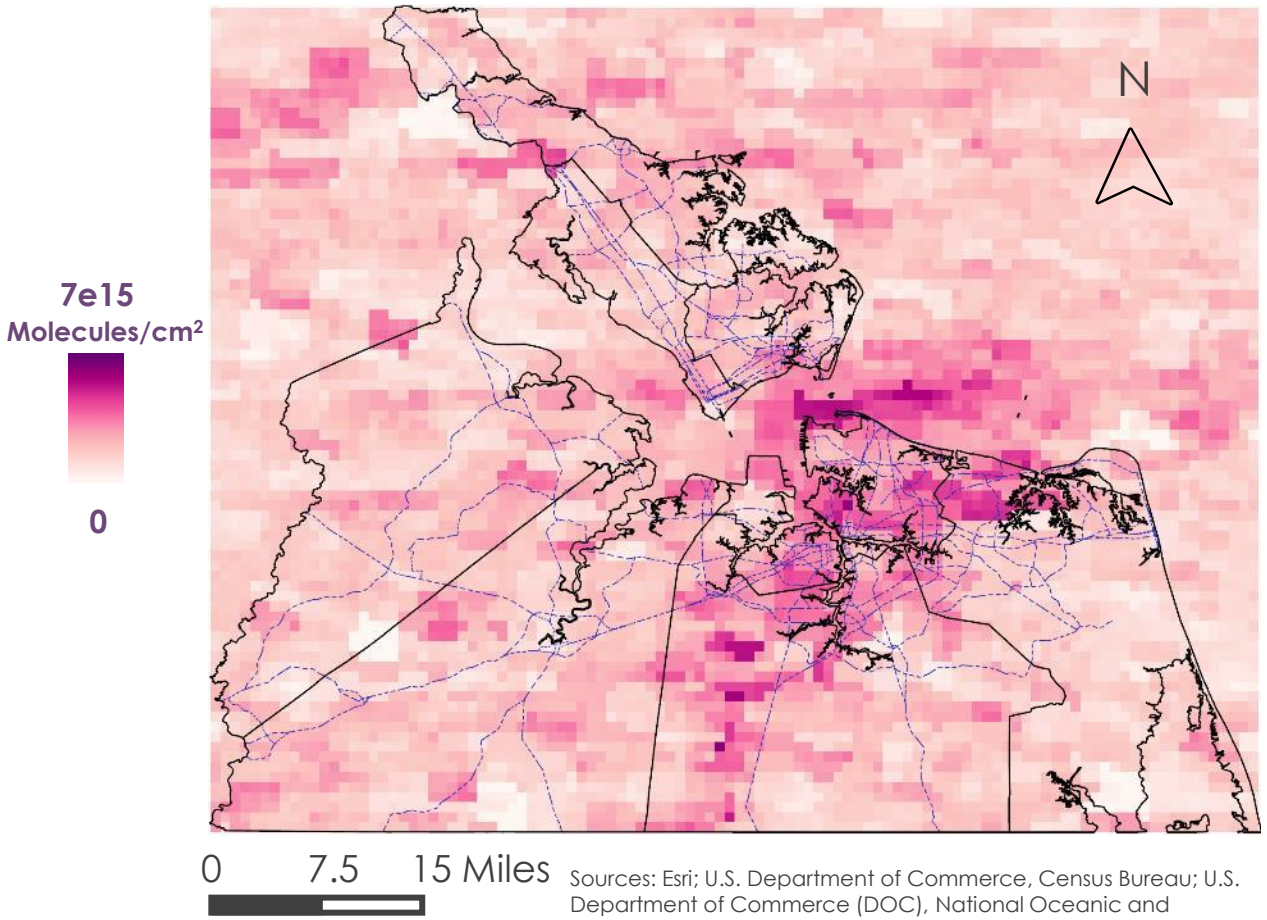
Sources: Esri; U.S. Department of Commerce, Census Bureau; U.S. Department of Commerce (DOC), National Oceanic and Atmospheric Administration (NOAA), National Ocean Service (NOS), National Geodetic Survey (NGS), NASA EarthData Search.

July 2024 Weekday Traffic Volume



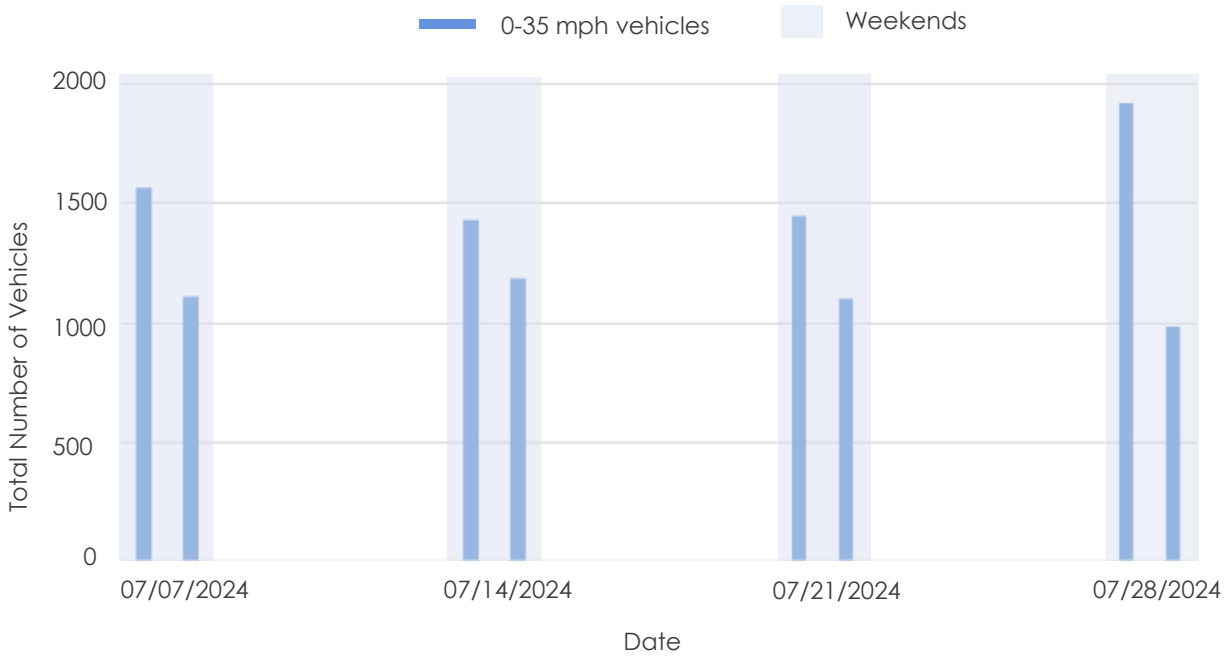
Oversampled TEMPO – Weekend Analysis

July Weekend TEMPO Tropospheric NO_2



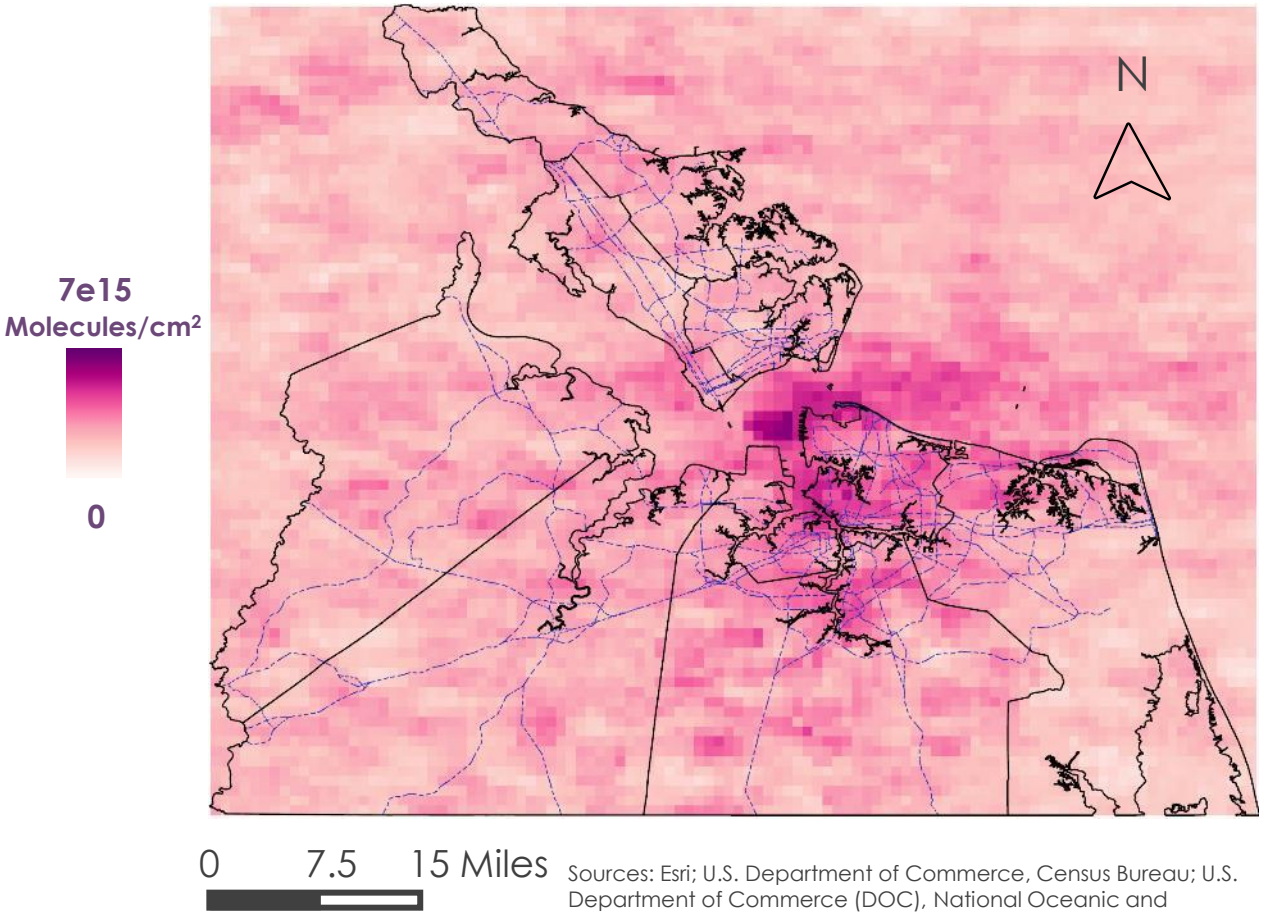
Sources: Esri; U.S. Department of Commerce, Census Bureau; U.S. Department of Commerce (DOC), National Oceanic and Atmospheric Administration (NOAA), National Ocean Service (NOS), National Geodetic Survey (NGS), NASA EarthData Search.

July 2024 Weekend Traffic Volume



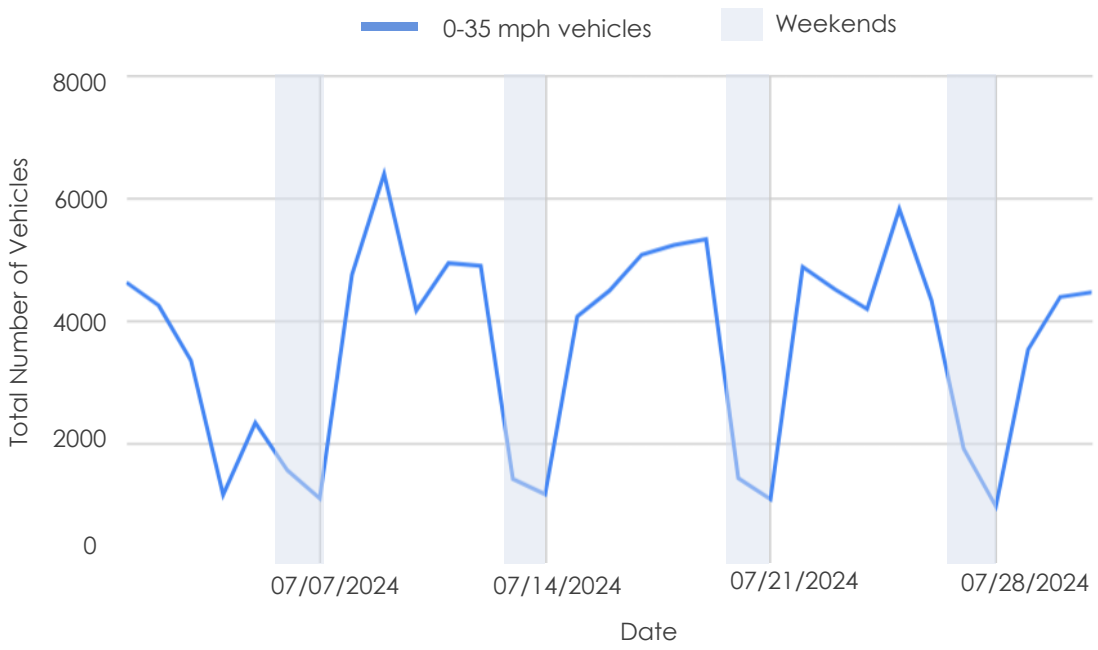
Oversampled TEMPO Monthly Analysis

July 2024 TEMPO Tropospheric NO2



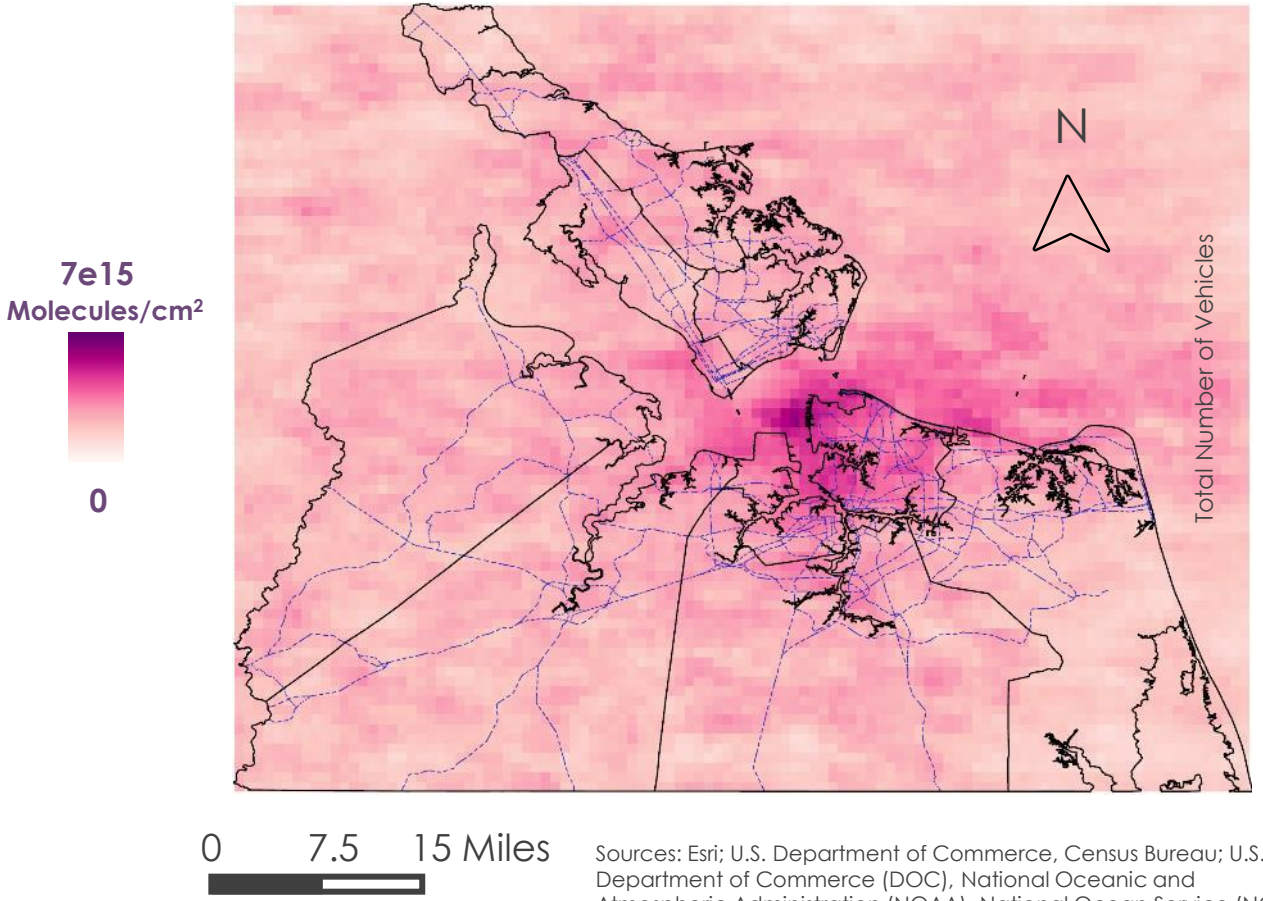
Sources: Esri; U.S. Department of Commerce, Census Bureau; U.S. Department of Commerce (DOC), National Oceanic and Atmospheric Administration (NOAA), National Ocean Service (NOS), National Geodetic Survey (NGS), NASA EarthData Search.

July 2024 Traffic Volume



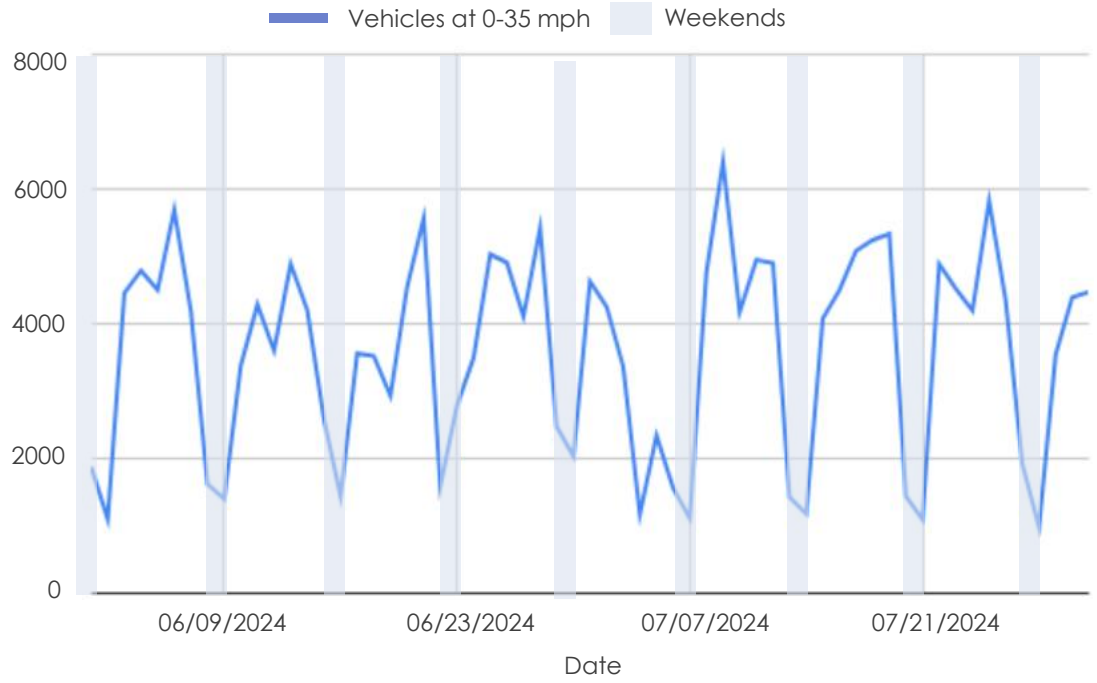
Oversampled TEMPO – Seasonal (Summer)

June and July 2024 TEMPO Tropospheric NO_2



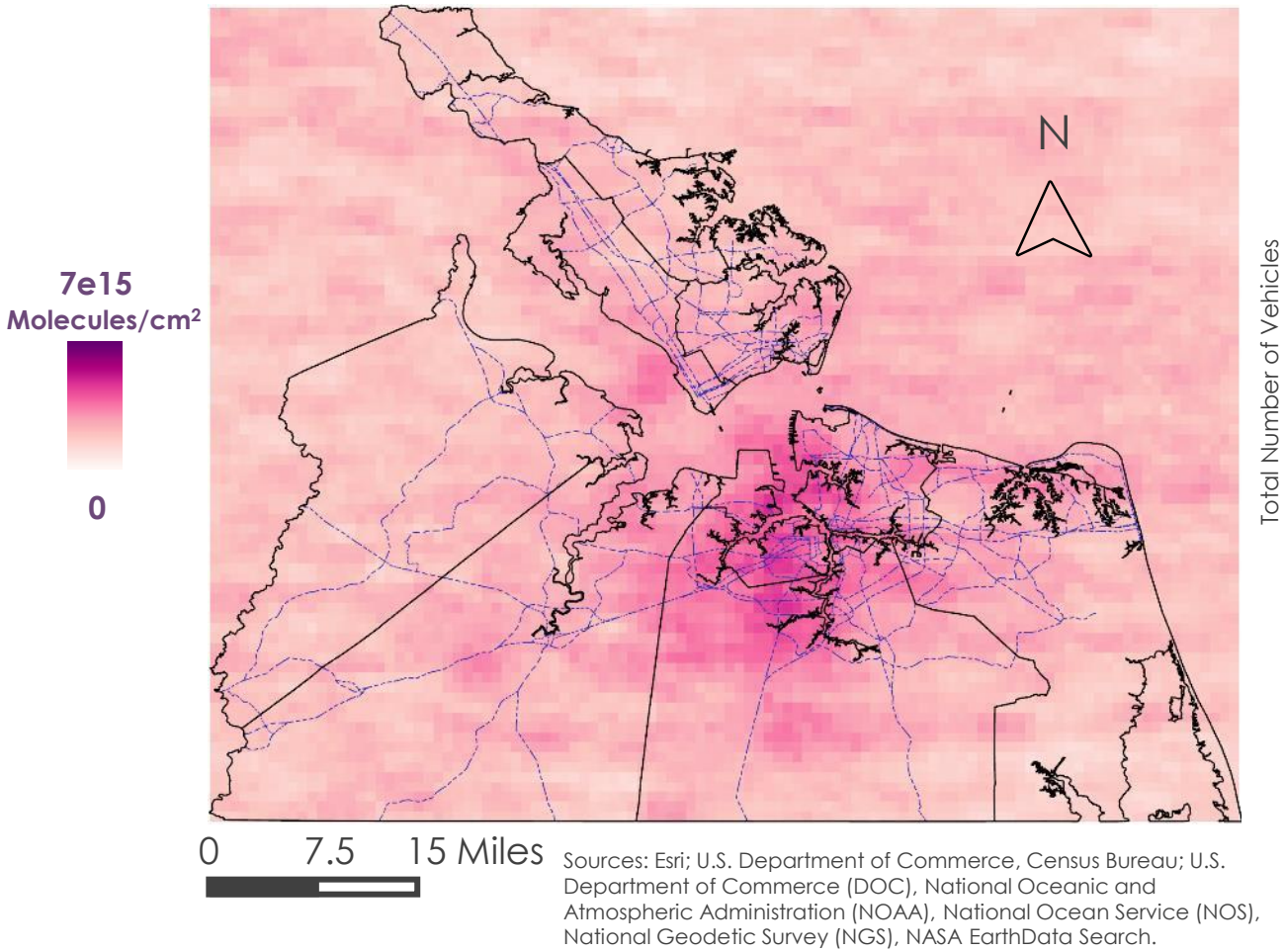
Sources: Esri; U.S. Department of Commerce, Census Bureau; U.S. Department of Commerce (DOC), National Oceanic and Atmospheric Administration (NOAA), National Ocean Service (NOS), National Geodetic Survey (NGS), NASA EarthData Search.

June and July 2024 Traffic Volume



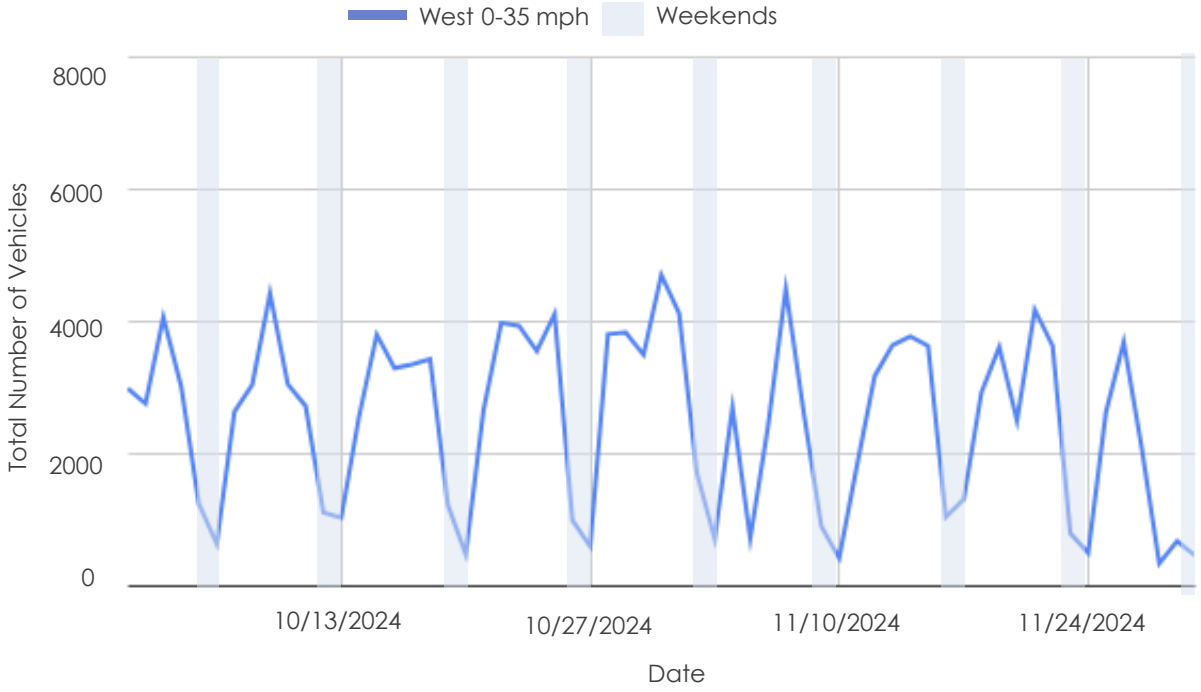
Oversampled TEMPO – Seasonal (Winter)

October – November 2024 TEMPO Tropospheric NO_2



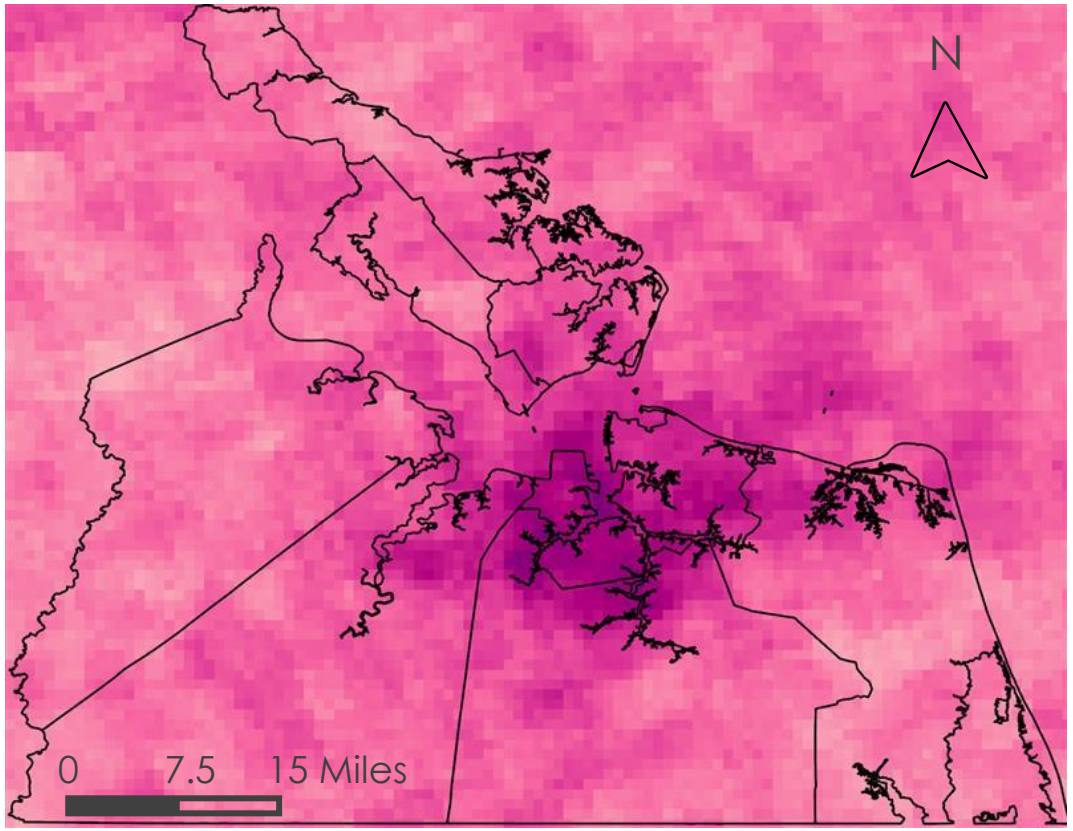
Sources: Esri; U.S. Department of Commerce, Census Bureau; U.S. Department of Commerce (DOC), National Oceanic and Atmospheric Administration (NOAA), National Ocean Service (NOS), National Geodetic Survey (NGS), NASA EarthData Search.

October – November 2024 Traffic Volume



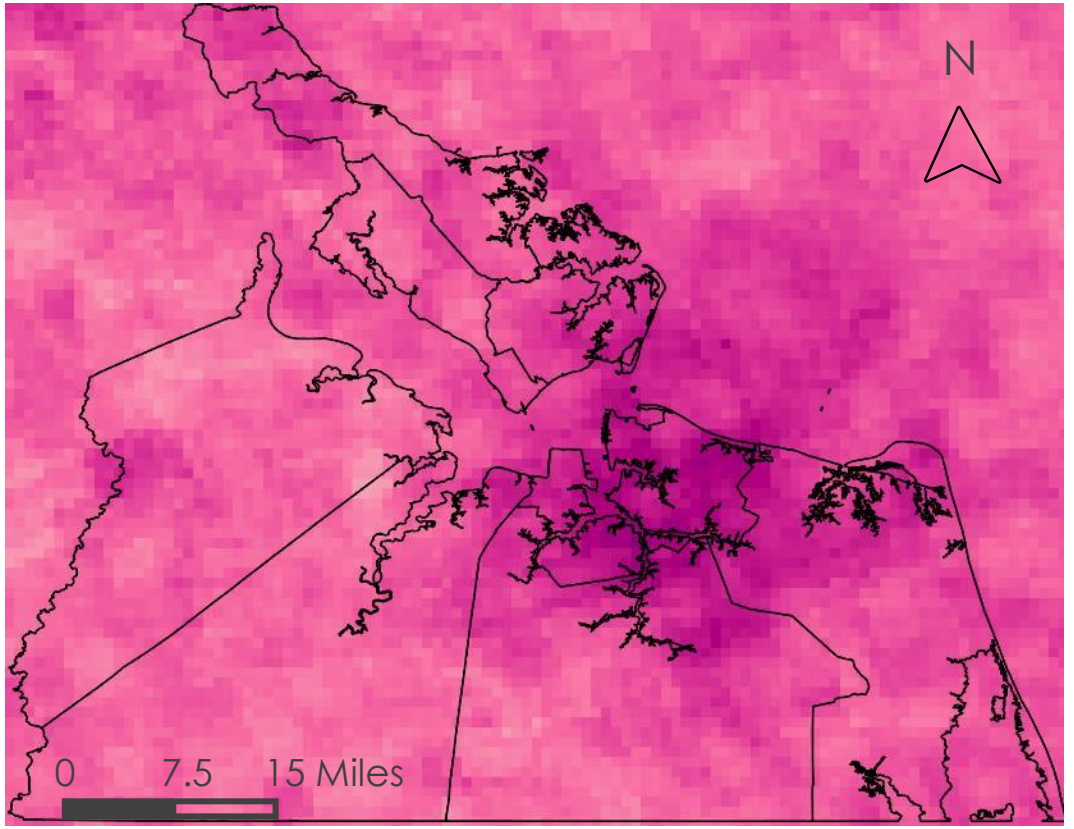
TROPOMI Before/During HRBT Expansion

TROPOMI Tropospheric NO_2



3.5e15
Molecules/cm²

0



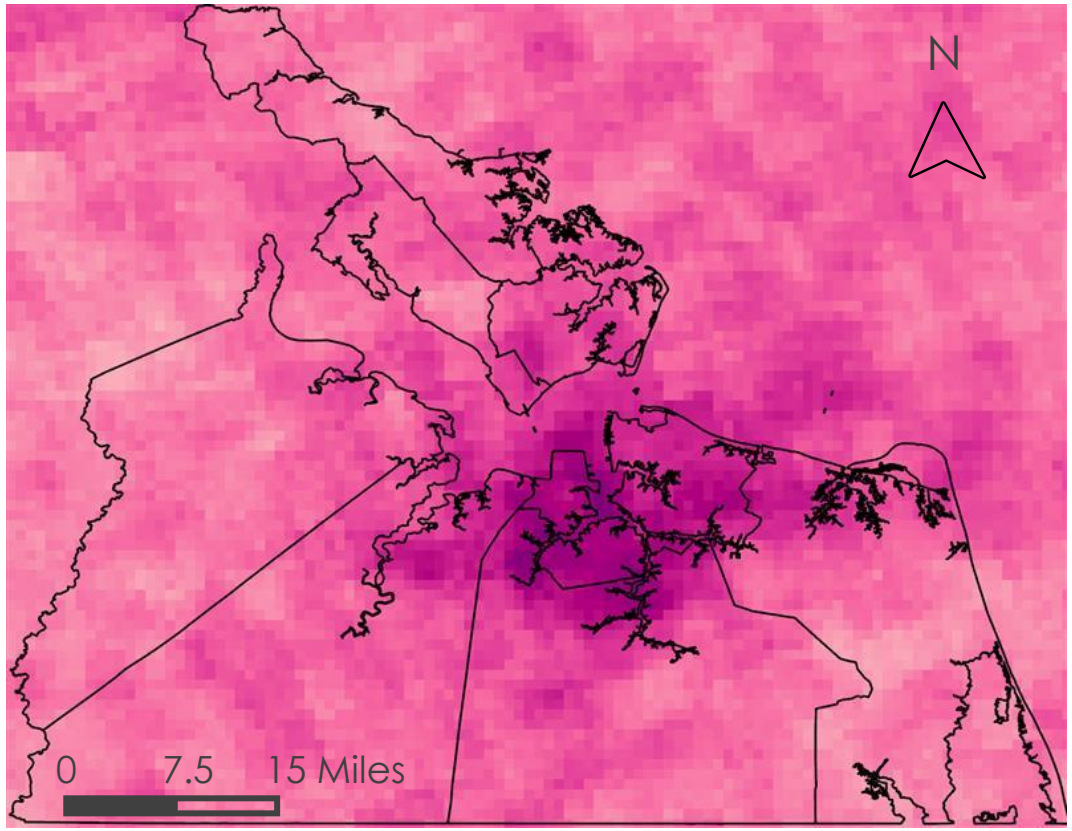
October 2020 (before)

October 2021 (during)

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.

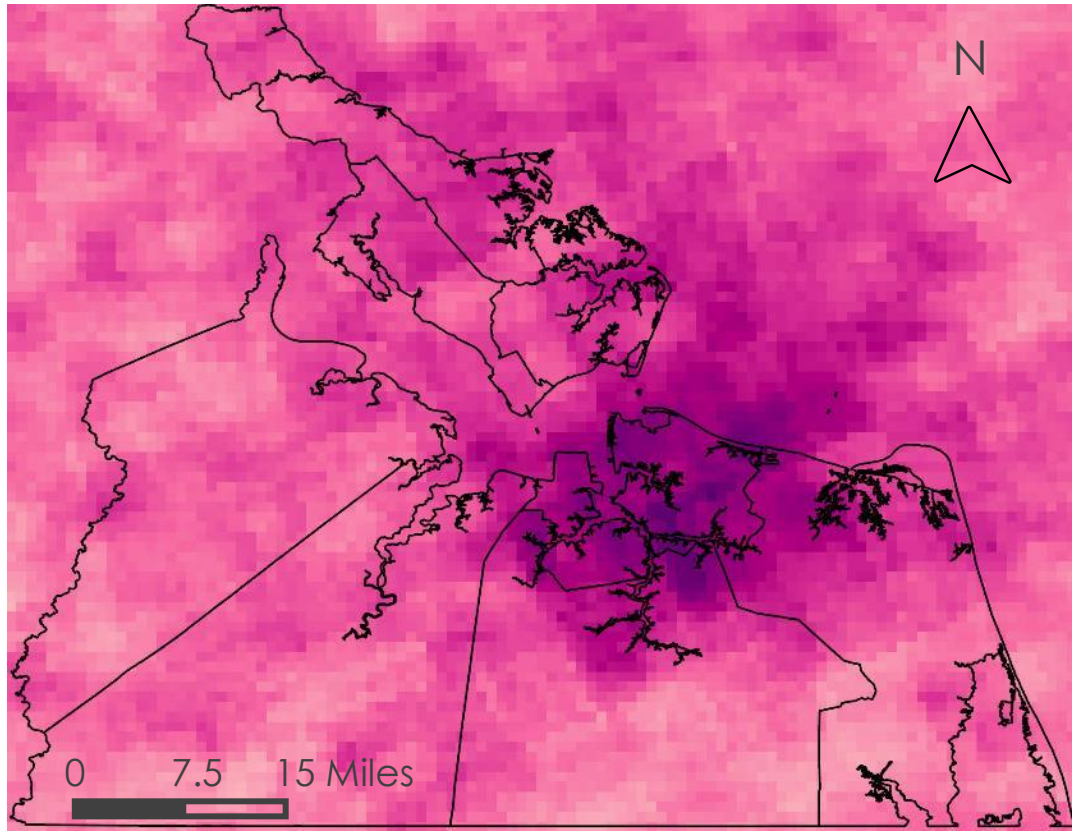
TROPOMI Before/During HRBT Expansion

TROPOMI Tropospheric NO_2



3.5e15
Molecules/cm²

0



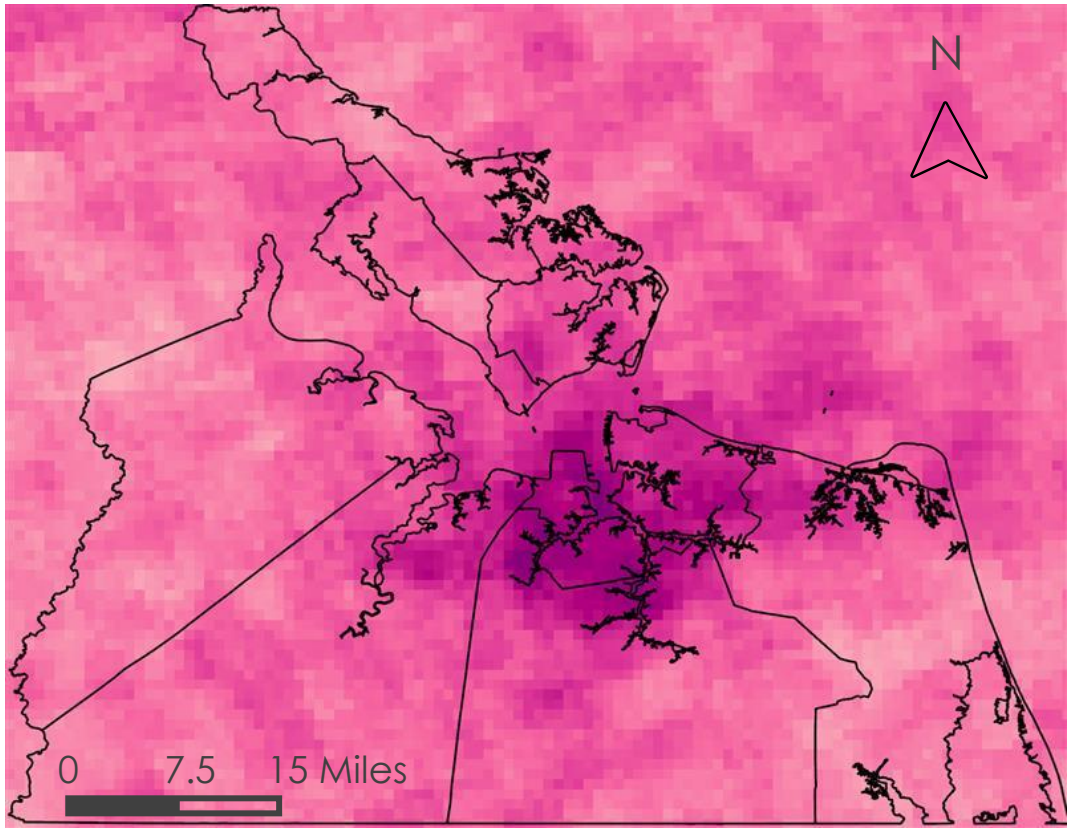
October 2020 (before)

October 2022 (during)

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.

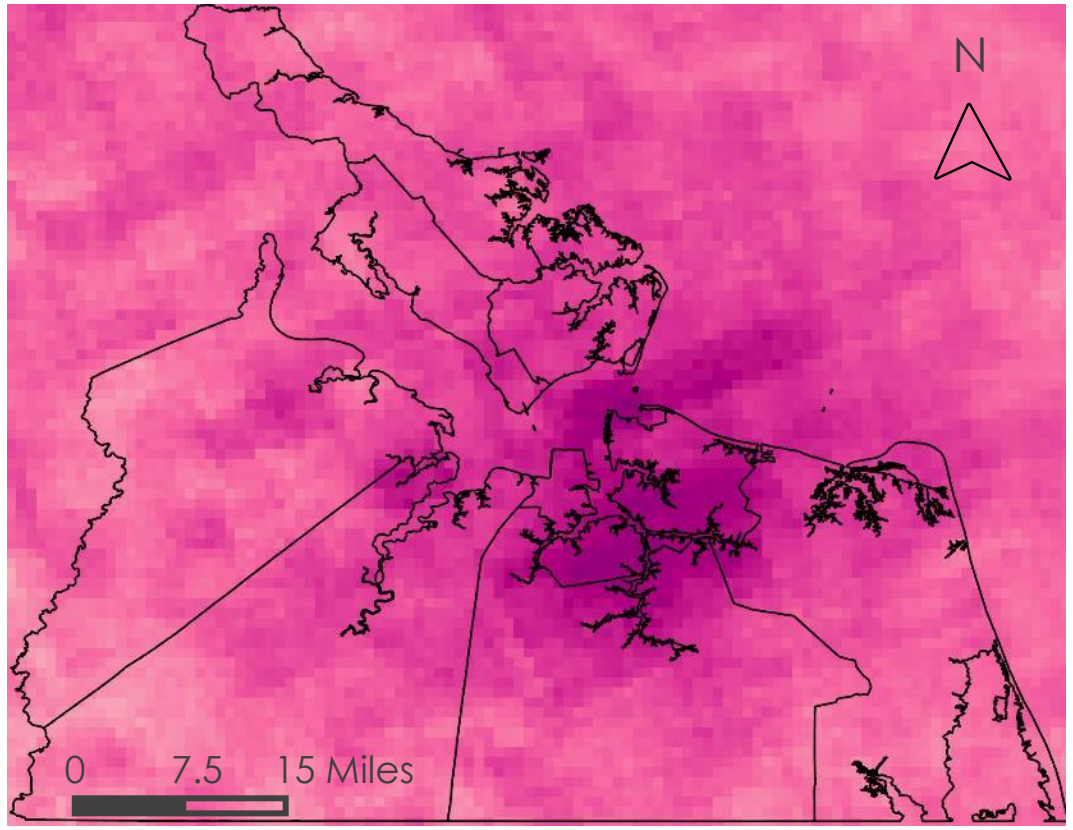
TROPOMI Before/During HRBT Expansion

TROPOMI Tropospheric NO_2



3.5e15
Molecules/cm²

0



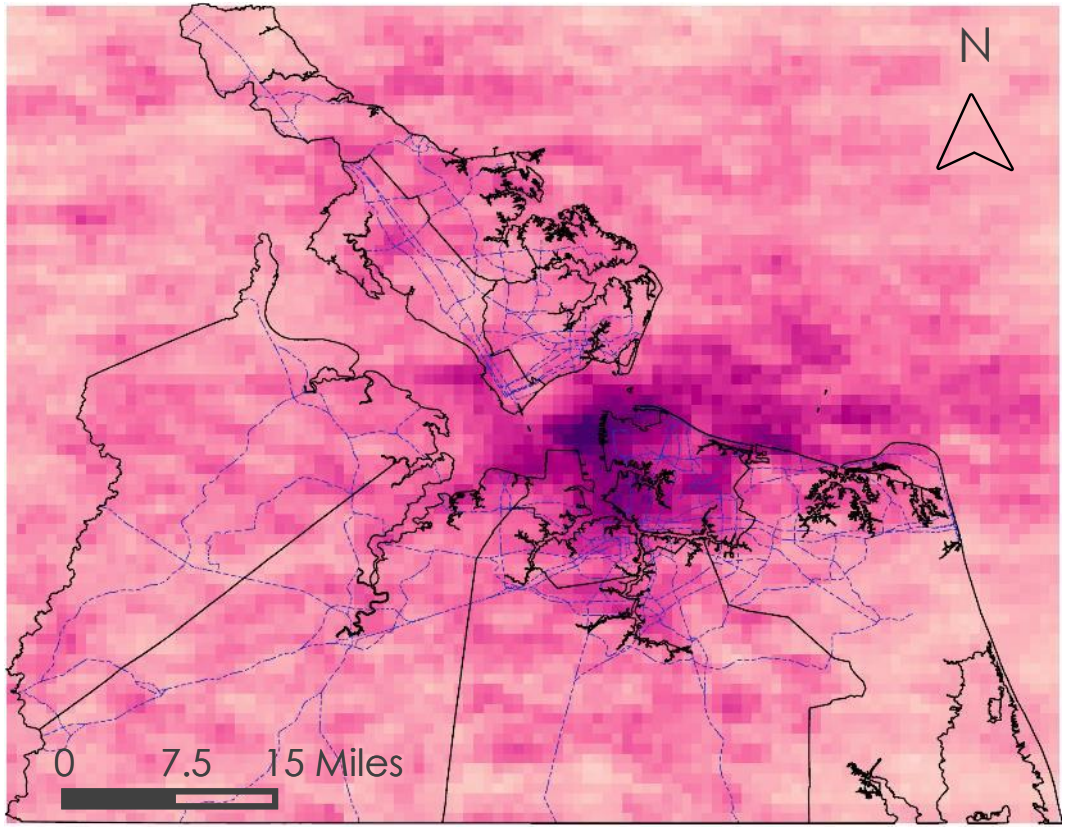
October 2020 (before)

October 2023 (during)

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.

TEMPO v. TROPOMI – June/July

TEMPO Tropospheric NO_2

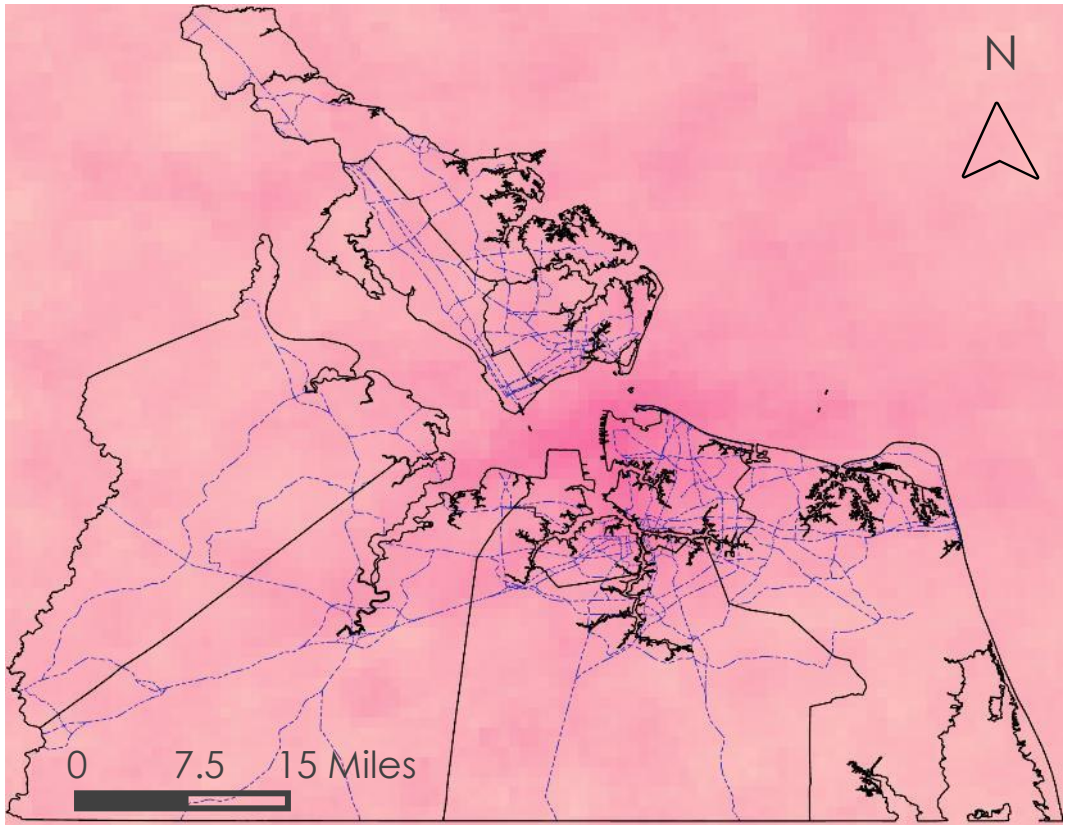


TEMPO

5e15
Molecules/cm²

0

TROPOMI Tropospheric NO_2

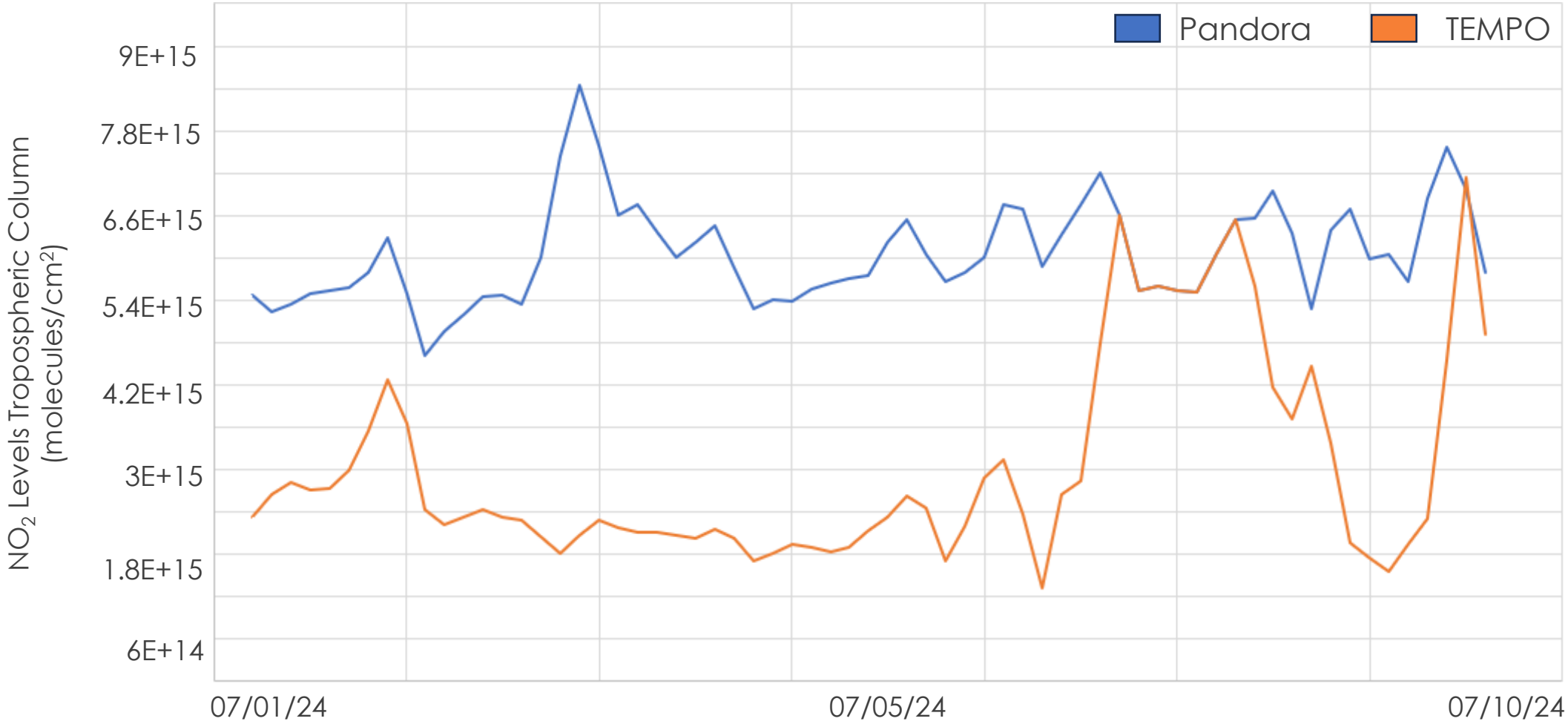


TROPOMI

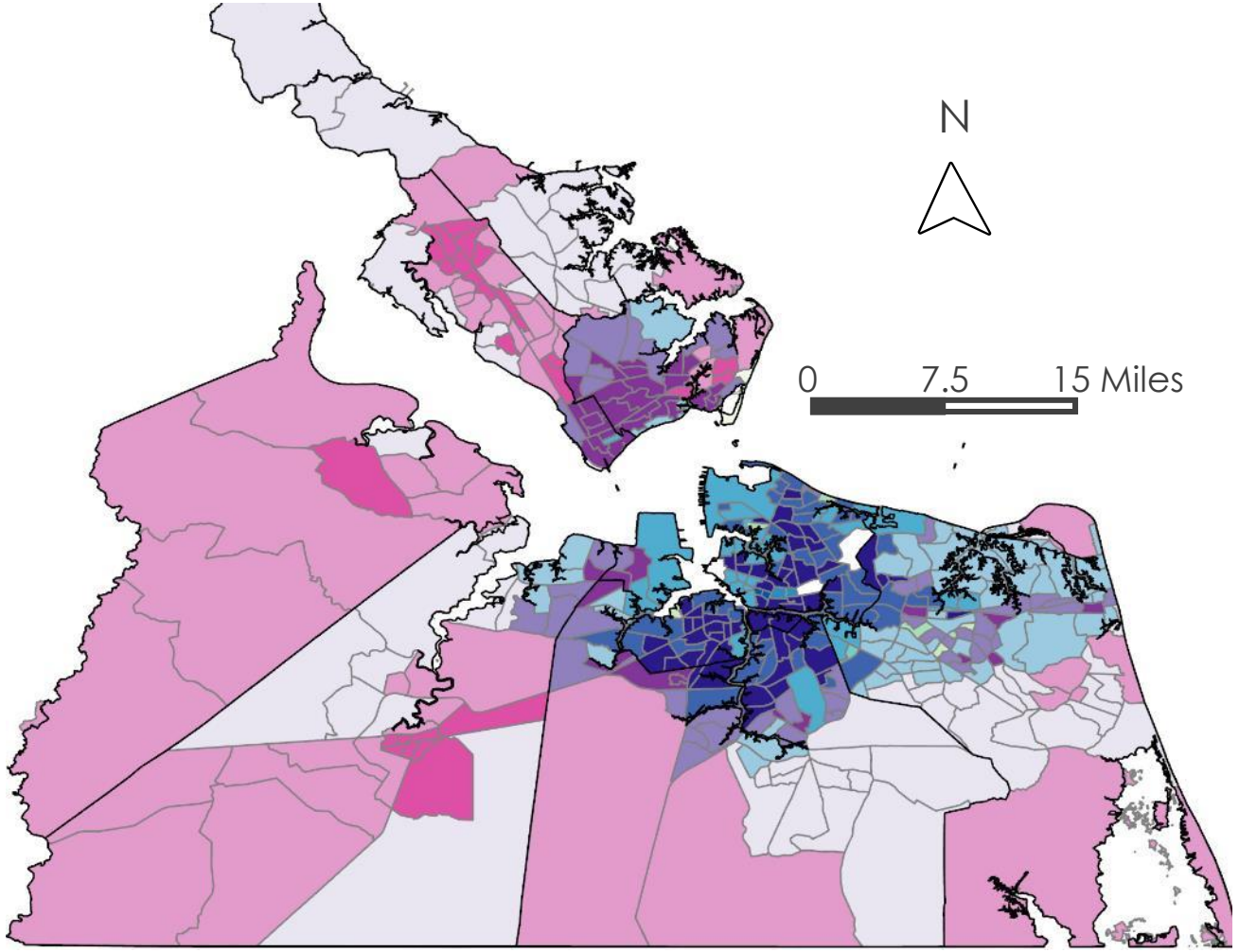
Sources: Esri; U.S. Department of Commerce, Census Bureau; U.S. Department of Commerce (DOC), National Oceanic and Atmospheric Administration (NOAA), National Ocean Service (NOS), National Geodetic Survey (NGS), NASA EarthData Search.

TEMPO v. Pandora (Two Week Analysis)

TEMPO v. Pandora (Trendlines of Hourly Averages)

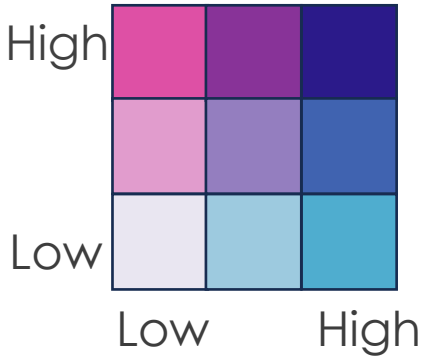


NO_2 and Asthma Prevalence Overlap



Asthma Prevalence (2024)

TROPOMI NO_2 Vertical Columns (2024 Average)



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.

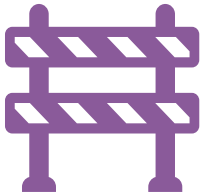
Limitations

Environmental:

- Cloud contamination
- Weather patterns
- Seasonal shifts in air quality

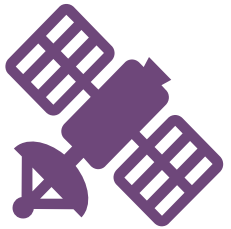
Construction:

- Unrelated interstate construction near the HRBT
- Maritime and other activity contributes to NO_2 levels



Satellites:

- Imperfect readings from the satellite instruments
- Data infrastructure still under development
- Used code lacks power to index specific time instances over long time periods without GIS analysis



Feasibility

TEMPO oversampling is a feasible tool for displaying NO_2 levels over multi-day periods at smaller areas, and ground observation validation

TEMPO measurements show feasibility for tracking short-term changes in NO_2 levels in Hampton Roads

Long term TEMPO and TROPOMI averages can be used in conjunction with health data to identify communities at risk of health effects

Conclusions

Oversampling can increase TEMPO'S spatial resolution to study geographically smaller areas than with provisional data products

NO_2 levels correlate with HRBT traffic patterns on various time scales

TEMPO temporal resolution allows for more feasible in-situ validation for shorter time scales

High levels of NO_2 and asthma prevalence see an overlap in Hampton and Norfolk

Partner Implementation

- **Public Information:** Keep the community informed about air quality concerns

- **Sensor Placement:** DEQ can use NASA Earth observations in the future to identify sensitive areas with high NO_2 levels that don't yet have ground sensors

- **Community Engagement:** Encourage community involvement in air quality projects

Acknowledgements

Project Partners:
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James Barringer – Office of Air Quality Monitoring, Virginia DEQ

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Data Provided By:
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Ian Turner – Virginia Department of Transportation

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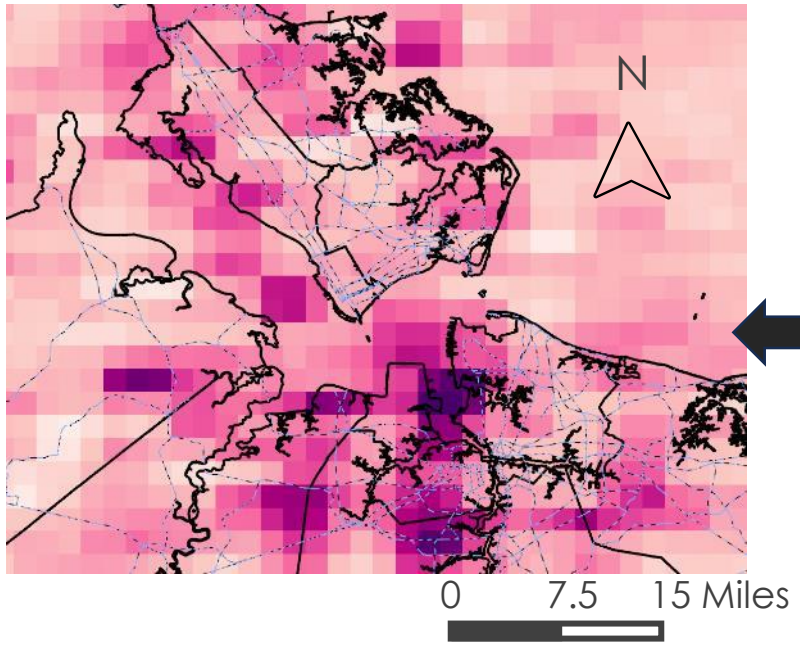
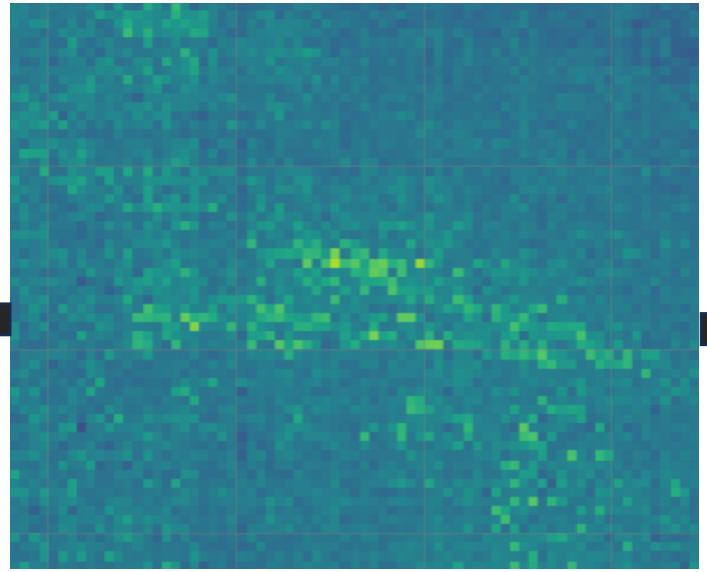
TEMPO Oversampling – Map Overview, July 2024

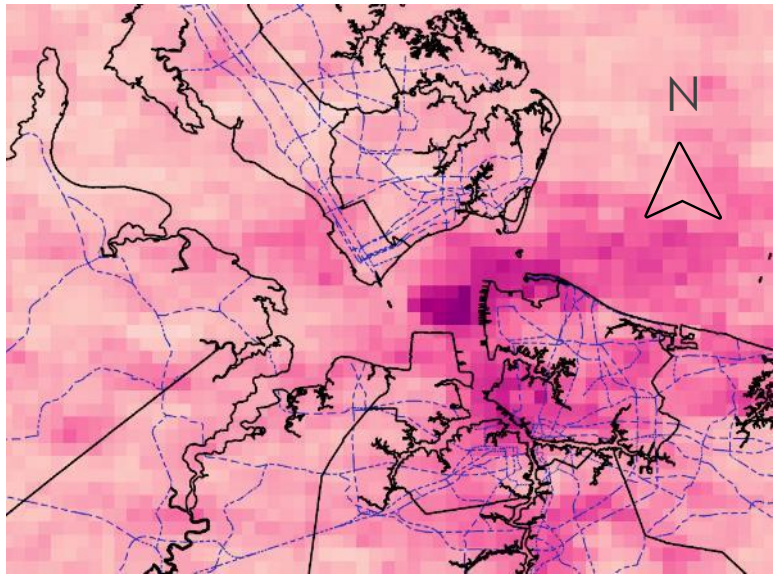
TEMPO temporal resolution allows for high spatial resolution L3 grids over shorter timescales



L3 Provisional
2 x 2 km² Grid



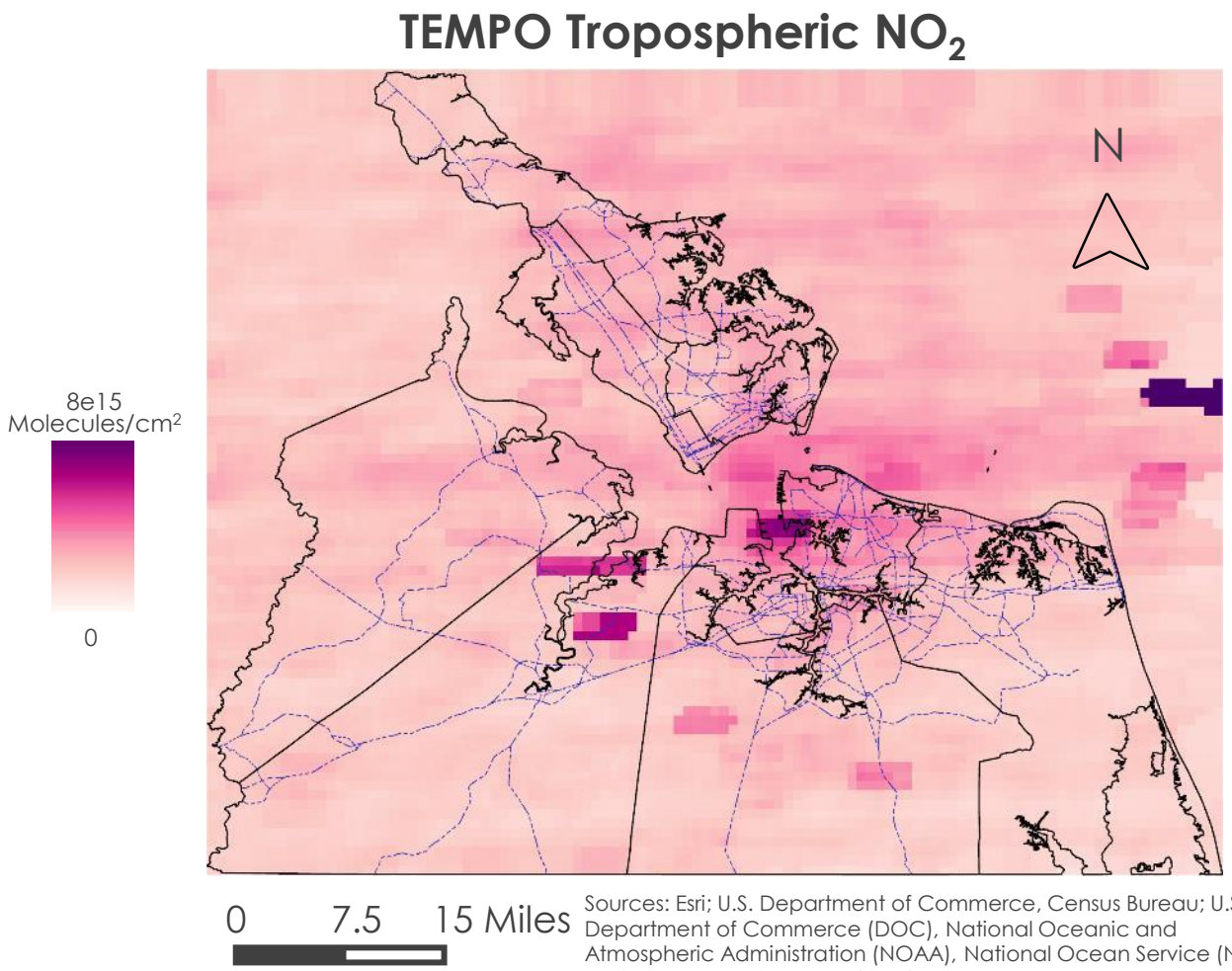
L2 Provisional
2 x 4.7 km² native resolution



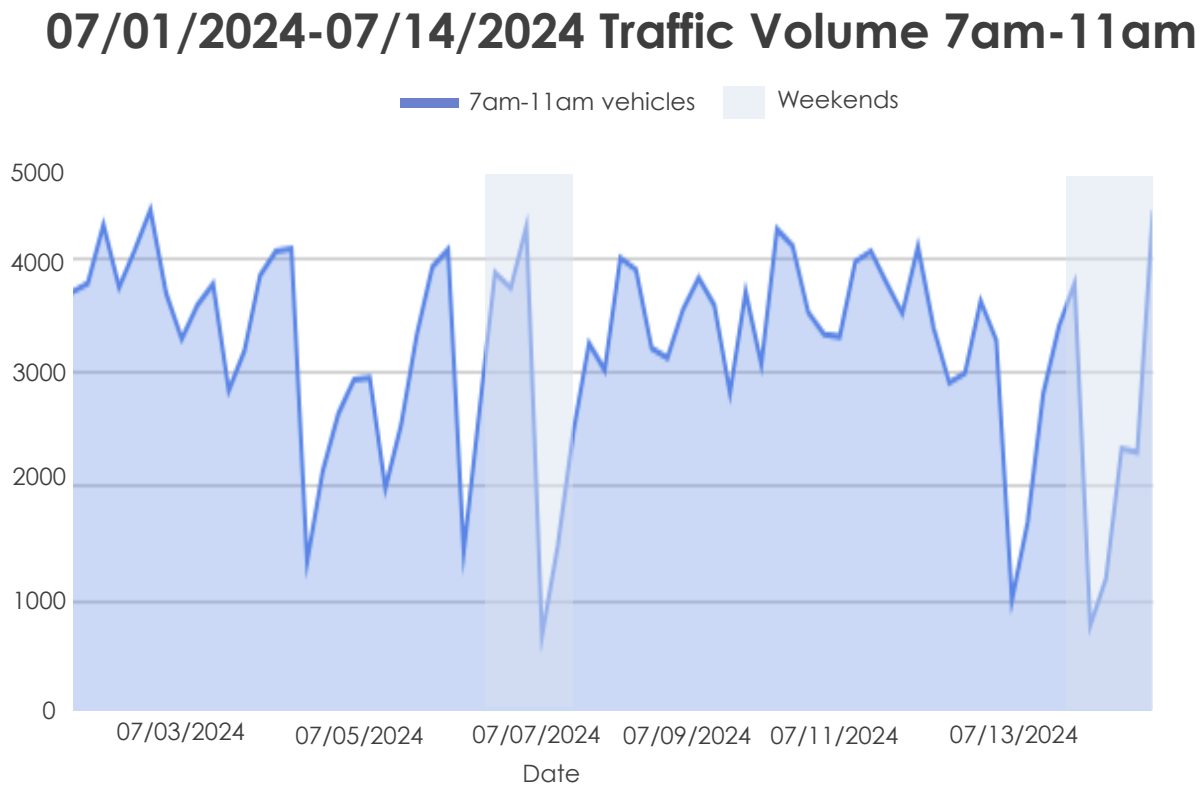
Oversampled
1 x 1 km² Grid

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.

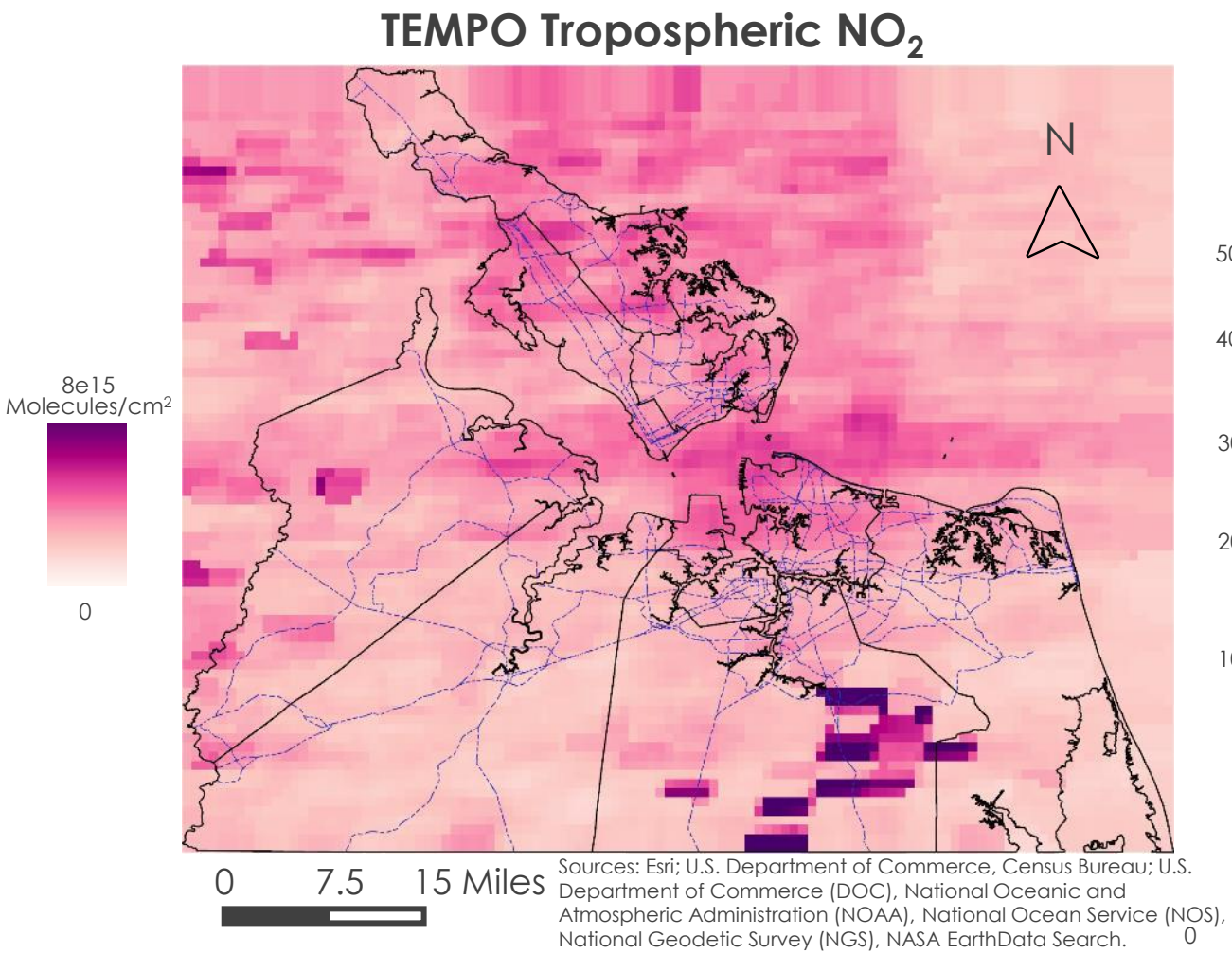
Oversampled TEMPO – Two Week Morning Analysis

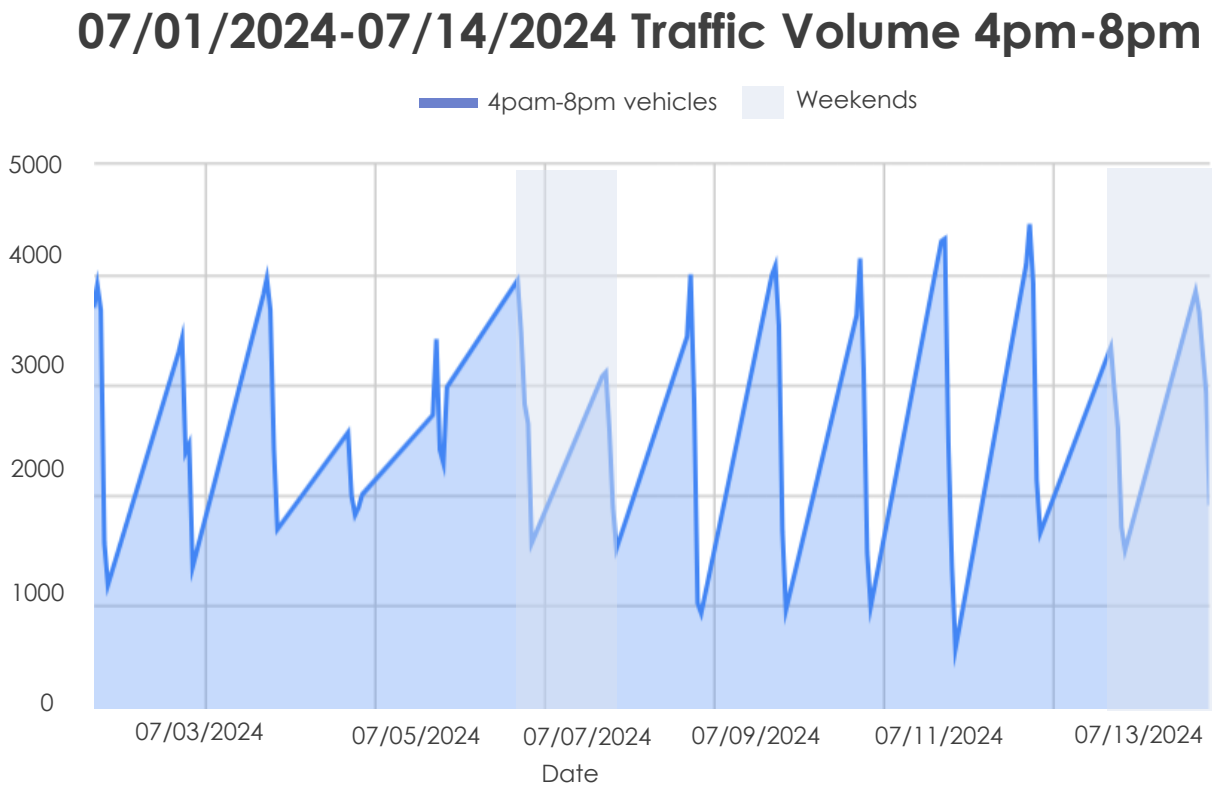


Sources: Esri; U.S. Department of Commerce, Census Bureau; U.S. Department of Commerce (DOC), National Oceanic and Atmospheric Administration (NOAA), National Ocean Service (NOS), National Geodetic Survey (NGS), NASA EarthData Search.



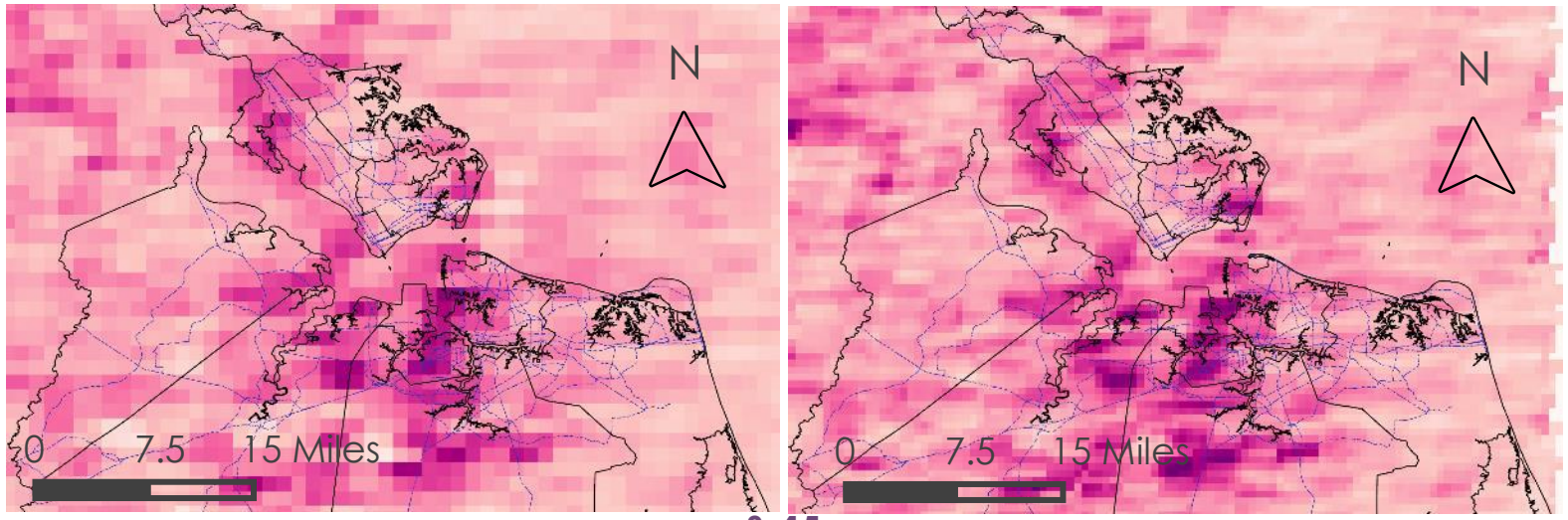
Oversampled TEMPO – Two Week Evening Analysis





Oversampled Individual Traffic Backup

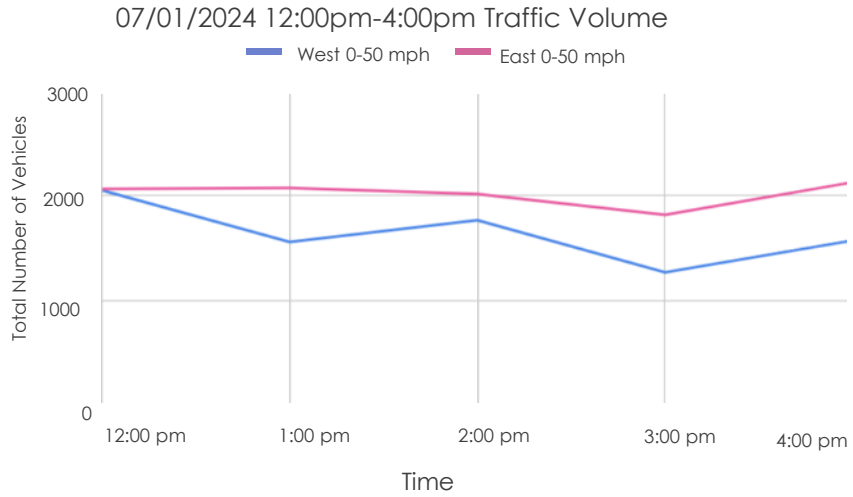
TEMPO Tropospheric NO_2 7/01/2024 12:00 -4:00pm



Provisonal Level 3

8e15
Molecules/cm²
0

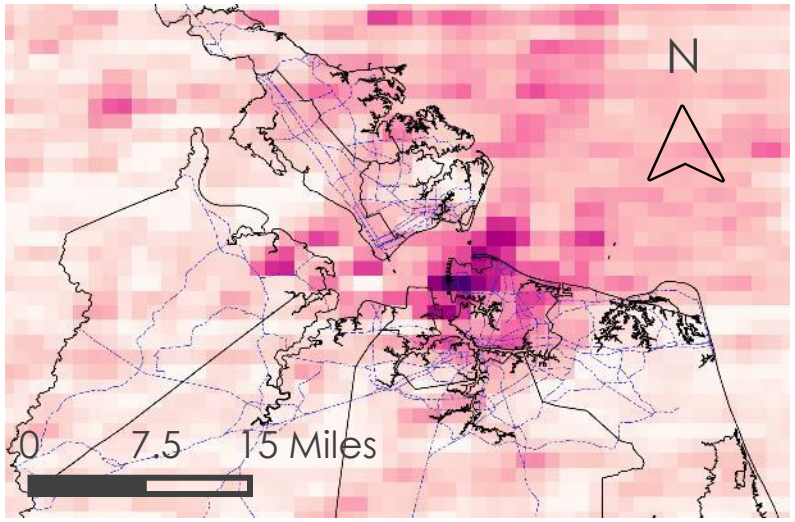
Oversampled



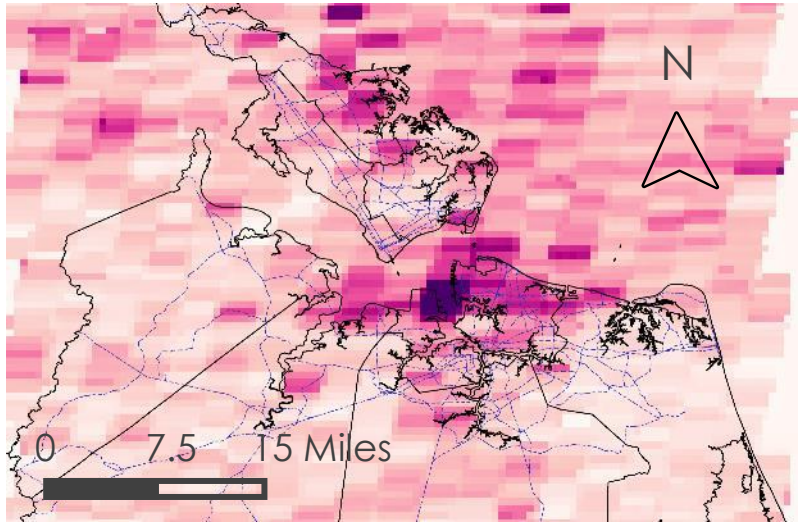
Sources: Esri; U.S. Department of Commerce, Census Bureau; U.S. Department of Commerce (DOC), National Oceanic and Atmospheric Administration (NOAA), National Ocean Service (NOS), National Geodetic Survey (NGS), NASA EarthData Search.

Oversampled TEMPO Individual Traffic Backup

TEMPO Tropospheric NO_2 6/13/2024 10:00 - 1:00pm



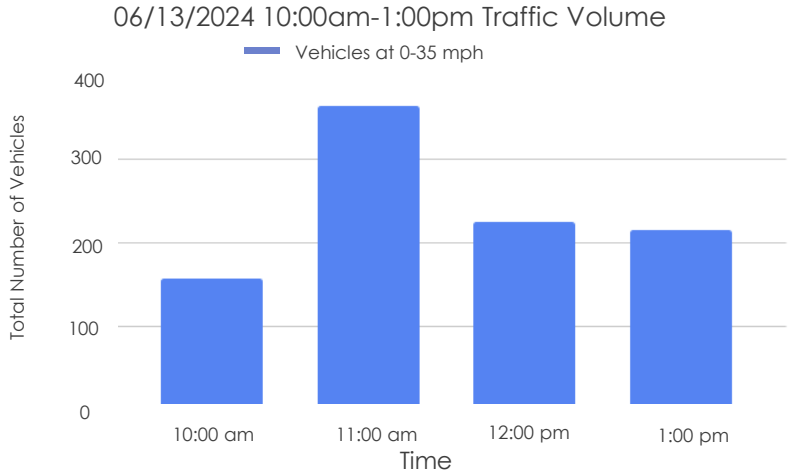
Provisional Level 3



Oversampled

8e15
Molecules/cm²

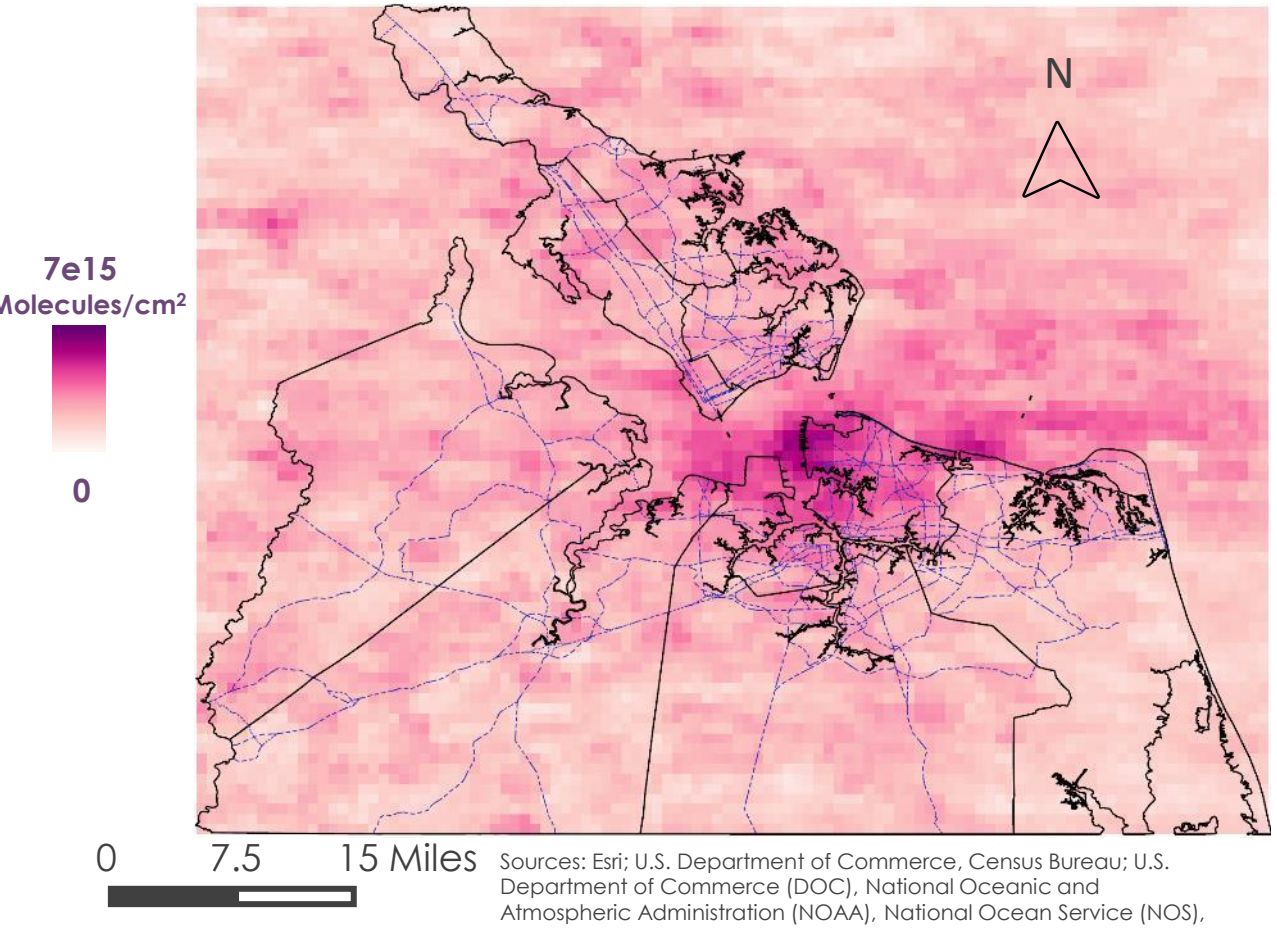
0



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.

Oversampled TEMPO Monthly Analysis

June 2024 TEMPO Tropospheric NO_2



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.

June 2024 Traffic Volume