Urban NOx Emissions from TEMPO

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CEOS AC-VC 22

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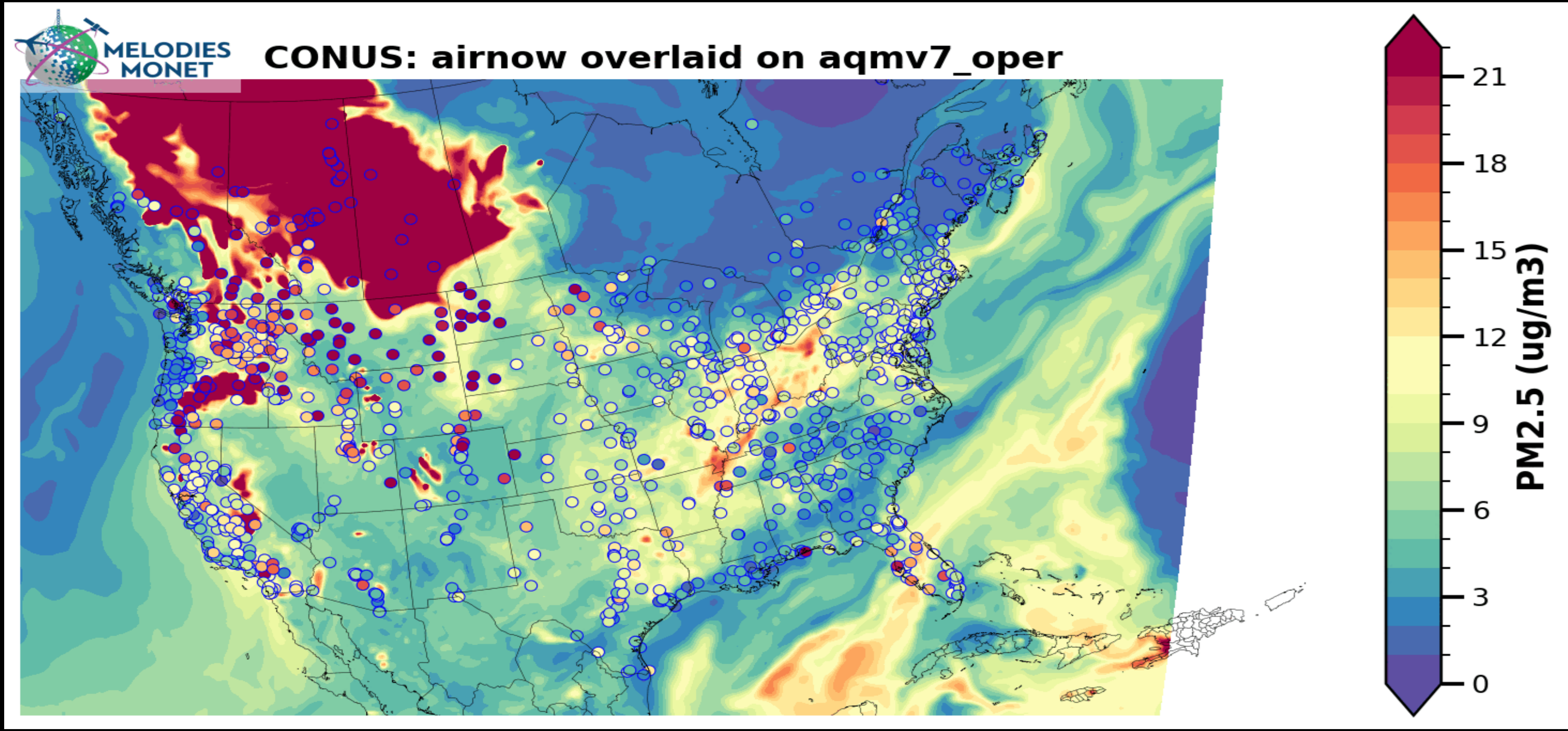
National Weather Service Unified Forecast System – Air Quality Model Forecast of Canadian Smoke July – August 2024

Anthropogenic emissions inventories and near real time satellite-based fire emissions drive the model forecasts for ozone and PM2.5.

Goal of deriving TEMPO urban NOx emissions is for timely updates of anthropogenic NOx emissions.



Barry Baker, NWS

NOAA's Community Emissions Computing Engine (CECE)

CECE is a modern, high-performance C++ software component designed to manage and calculate atmospheric emissions for Earth system models. It is built as a next-generation tool for the Unified Forecast System (UFS) community, functioning similarly to legacy systems like HEMCO (Harvard-NASA Emissions Component) but optimized for modern computing architectures.

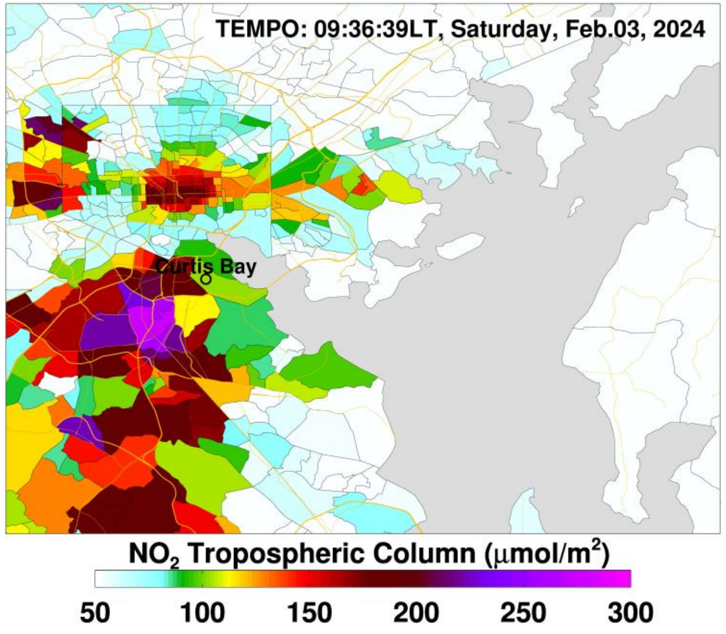
CECE's hybrid ingestion allows for:

Offline

- Emissions derived using satellite data via data assimilation and inverse modeling.
- Use satellite-based emissions to derive time-varying and space-varying scaling factors to adjust base inventory.

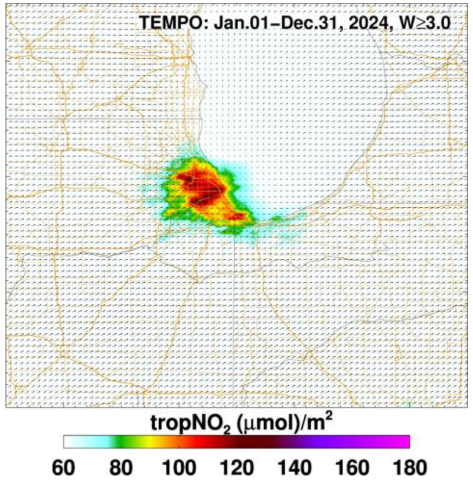
Inline

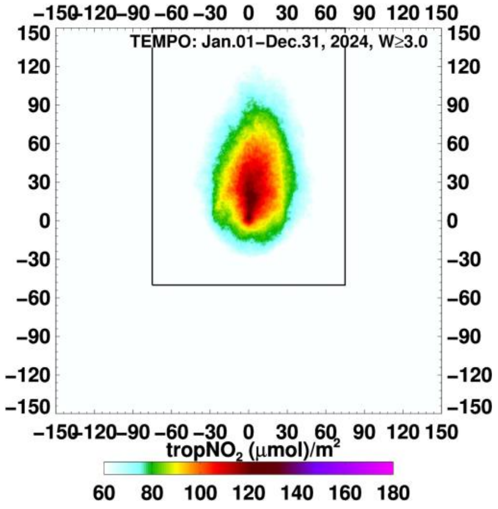
- Weather driven emissions where the weather information comes from the model itself (e.g., dust emission).

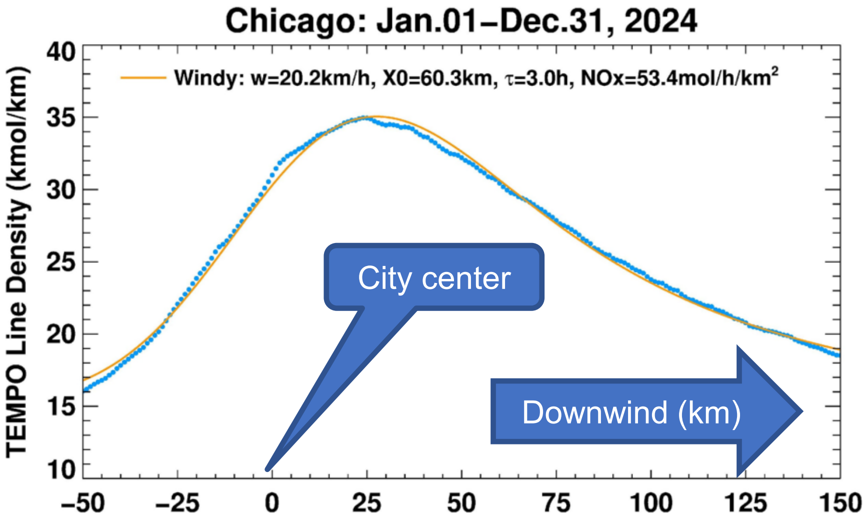


CECE Lead: Barry Baker (NWS)

Exponentially Modified Gaussian (EMG) Method Applied to TEMPO and TROPOMI







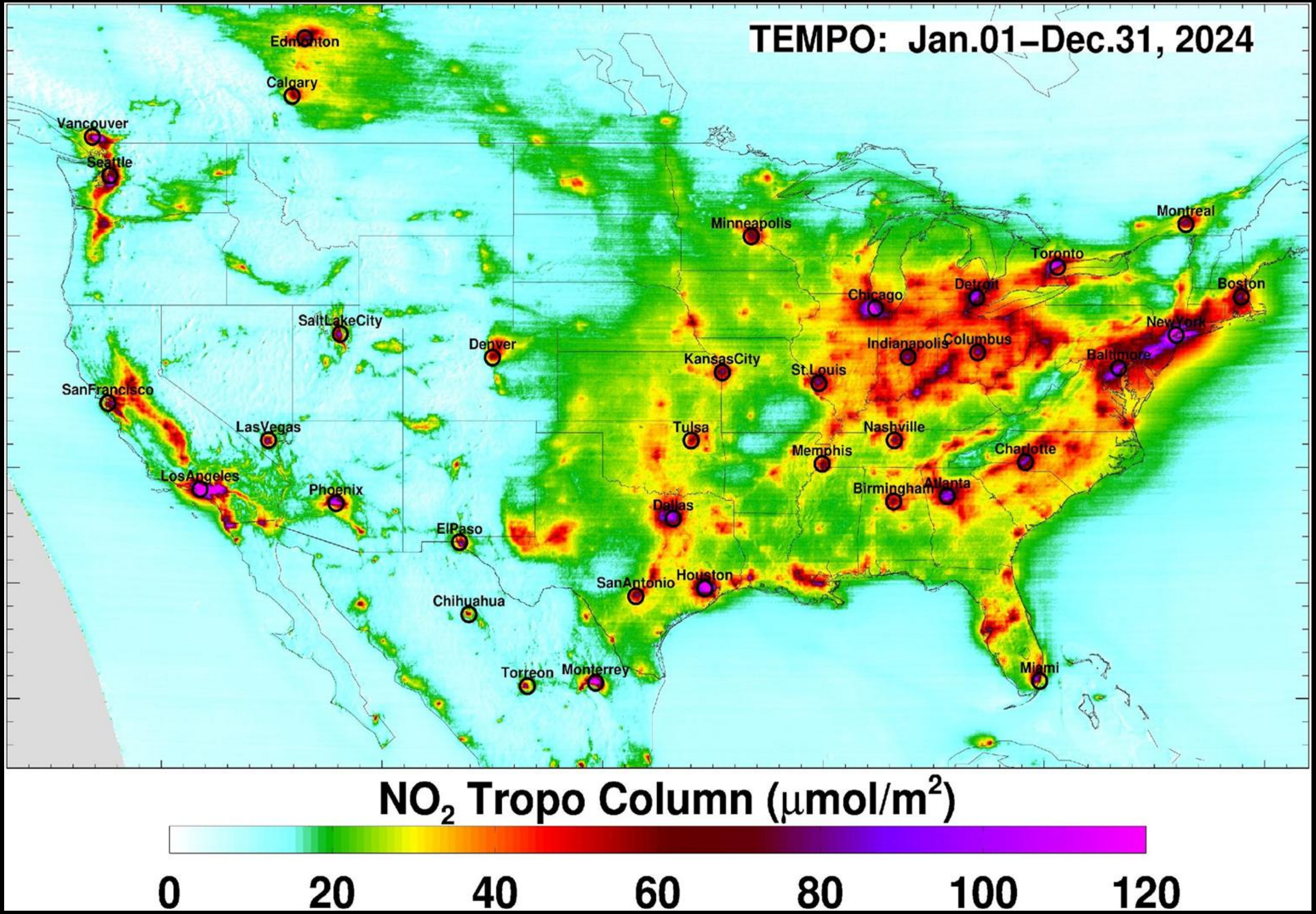
$$f(x) = \alpha \left[\frac{1}{x_0} e^{\left(\frac{\mu}{x_0} + \frac{\sigma^2}{2x_0^2} - \frac{x}{x_0} \right)} \Phi \left(\frac{x-\mu}{\sigma} - \frac{\sigma}{x_0} \right) \right] + B$$

- Φ -- cumulative distribution function,
- x_0 -- e-folding distance downwind,
- α --- NO_2 enhancement,
- B --- background NO_2,
- μ --- location of the apparent source,
- σ --- standard deviation of the Gaussian function.

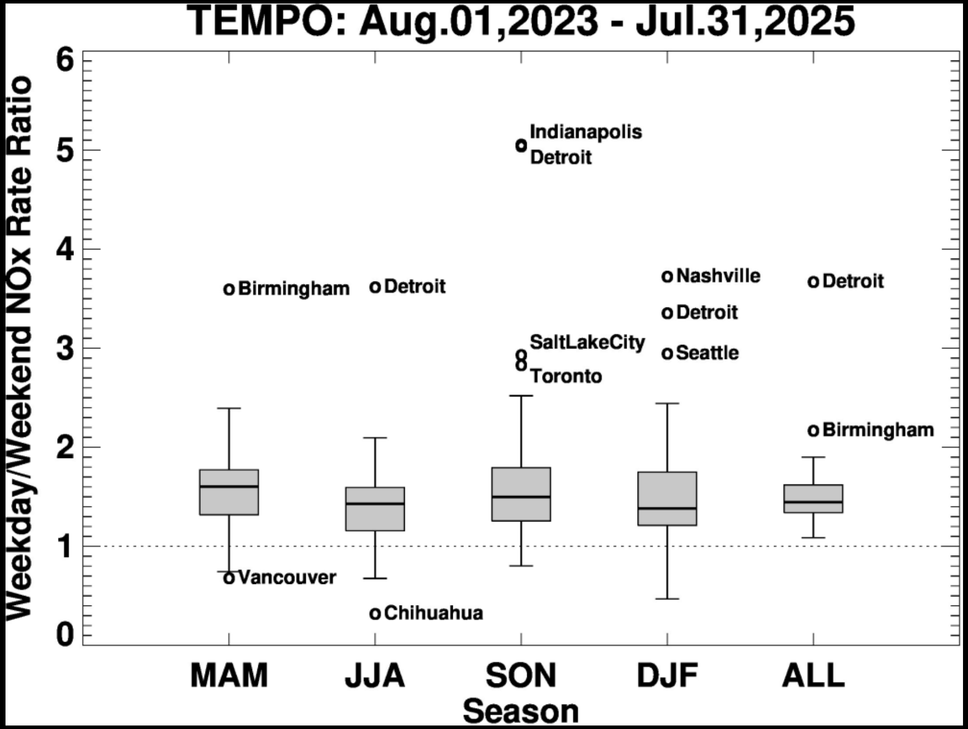
$$\tau = \frac{x_0}{w} \qquad E = 1.33 \cdot \frac{\alpha}{\tau}$$

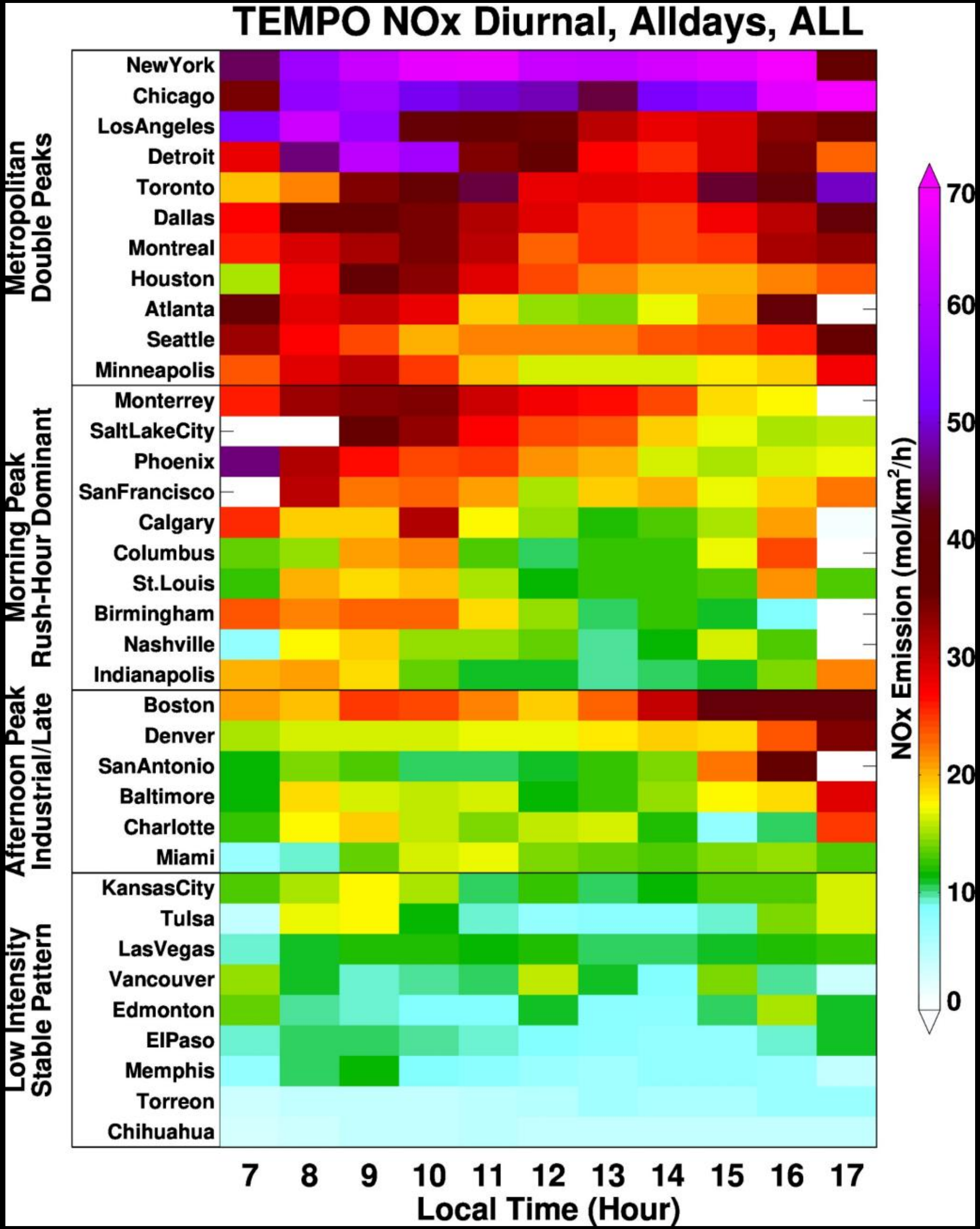
Selection of Urban Areas

- City selection is based on the major hotspots on TEMPO tropNO_2 annual mean maps.
- Fitting period: Jan.01—Dec.31, 2024, all days and all scans of TEMPO were included.
- Fitting domains: 30~75km in the upwind, 50~200km in the downwind, 30~100km in the cross wind directions. Depends on the pollution plume range from TEMPO annual mean.



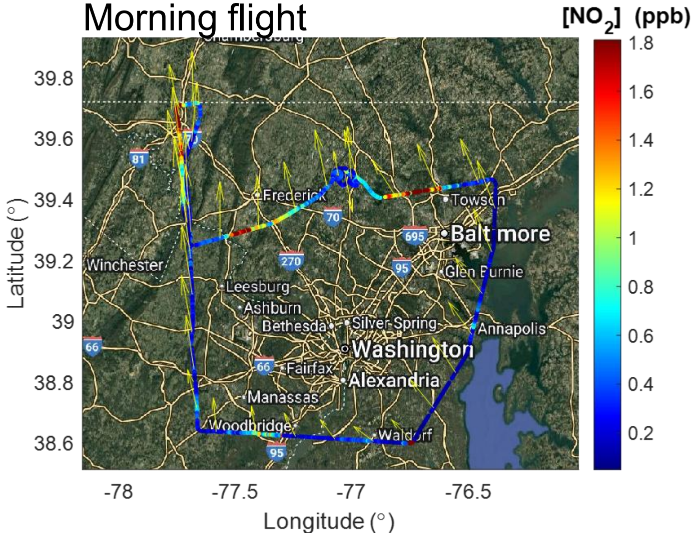
Urban areas can be grouped by emissions peaks in the afternoon, morning, morning and evening.



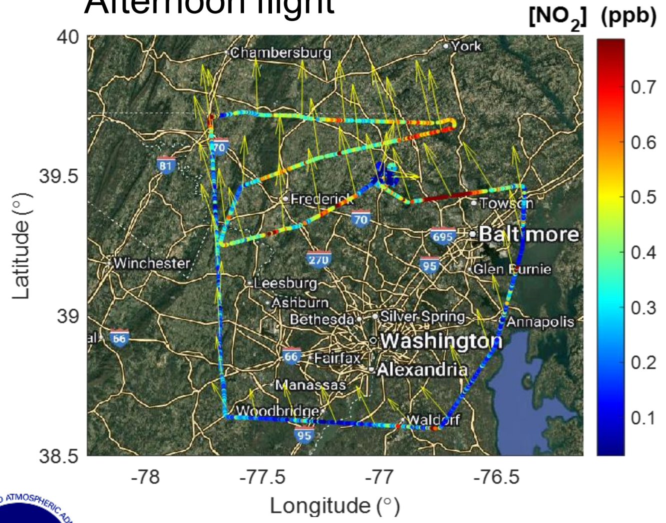


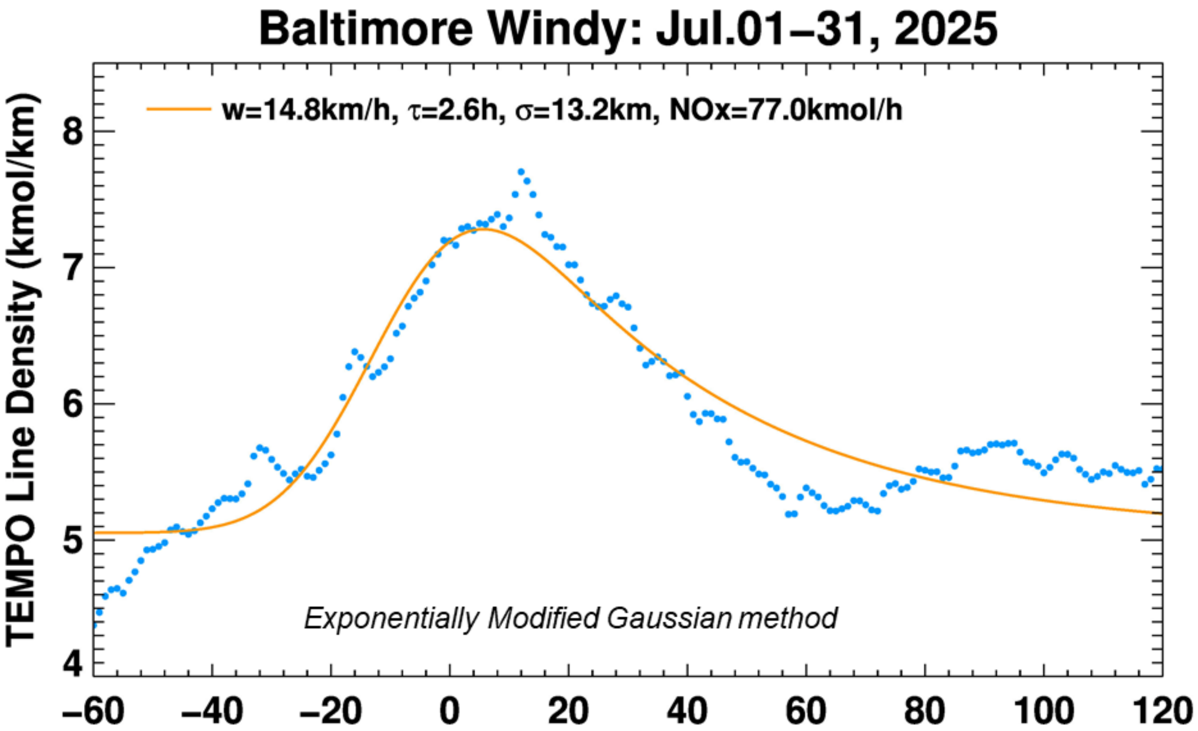
July 23, 2025 aircraft flights

Morning flight



Afternoon flight



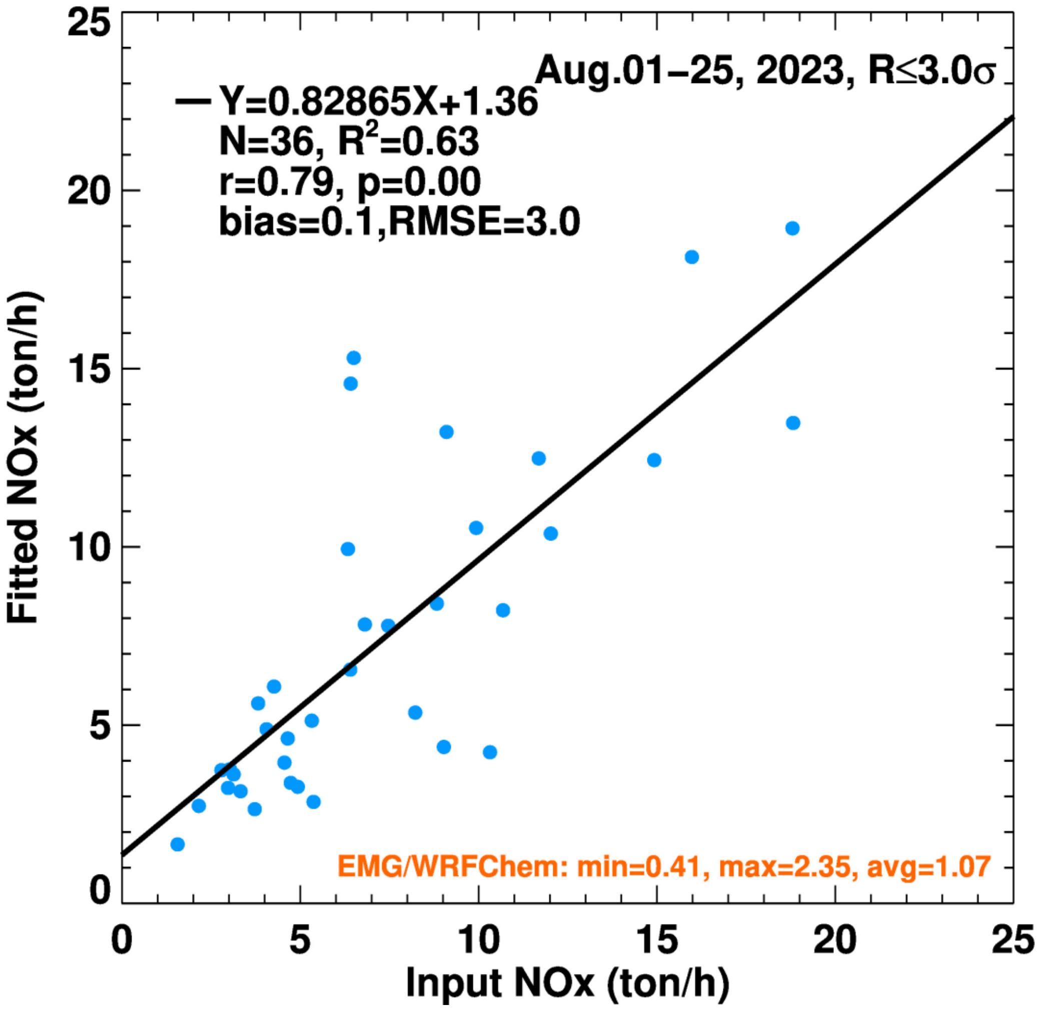


System	NOx Flux (kg/hr)
TEMPO (July 2025)	803.16
Aircraft (July 2025)	657

EMG emissions are sensitive to data selection and the area used to represent the city. These results are for windy conditions (>3 m/s) and area under the curve calculated for 3-sigma. For cities like Baltimore in close proximity to other major sources, careful data selection is needed.

Independent Verification of EMG

- ❖ Run EMG method on model forecast of tropNO2. Because the model uses known emissions, we can compare them to those derived from EMG.
- ❖ All else (fitting domain, wind fields, realigning pixels in the wind direction) etc. in the EMG



Conclusions

- Conducted initial analysis to understand if the EMG method can be applied to TEMPO tropNO2 data on an hourly basis and demonstrated that it can be done;
- Will conduct additional testing of the EMG method on TEMPO data for power plants in the US
  - Continuous Emissions Data Set from EPA serves as a useful reference to verify the EMG method
- Conduct case study analysis for drastic changes in NOx emissions
  - Baltimore key bridge collapse
- Repeat the analysis with V4 reprocessed TEMPO tropNO2 data