NO_2 Impacts of Airport-Related Sources with AERMOD's Five Chemistry Approaches

20^{th} Annual CMAS Conference 2021

A Wood – EPA collaborative effort

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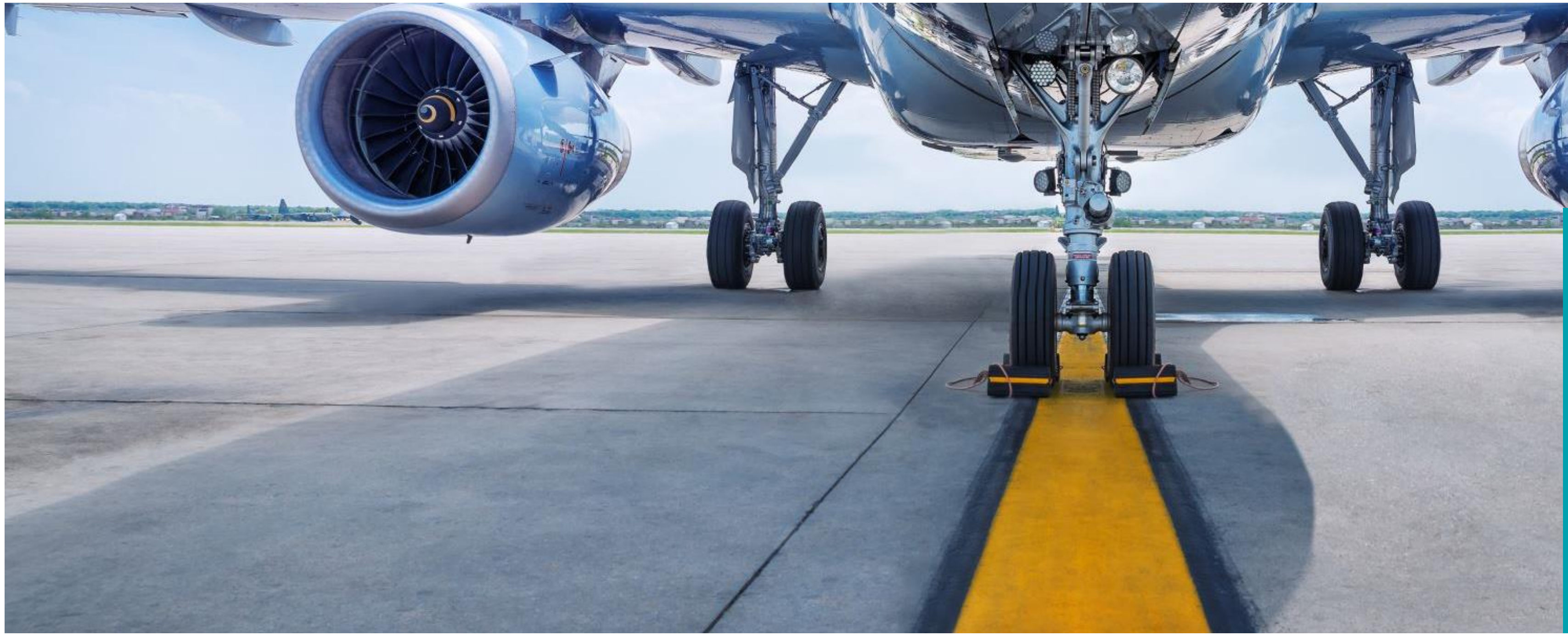

- Model to Monitor Comparison for NO_2
- Sensitivity Analysis of AERMOD's Five Chemistry Methods

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Outline

What is AERMOD?

Objective

Methods Background

- Model Parameters
- Source Characterization

Chemistry Methods

- Ambient Ration Method (ARM2)
- Ozone Limiting Method (OLM)
- Plume Volume Molar Ratio Method (PVMRM)
- Travel Time Reaction Method (TTRM)
- Generic Reaction Set Method (GRSM)

Conclusions

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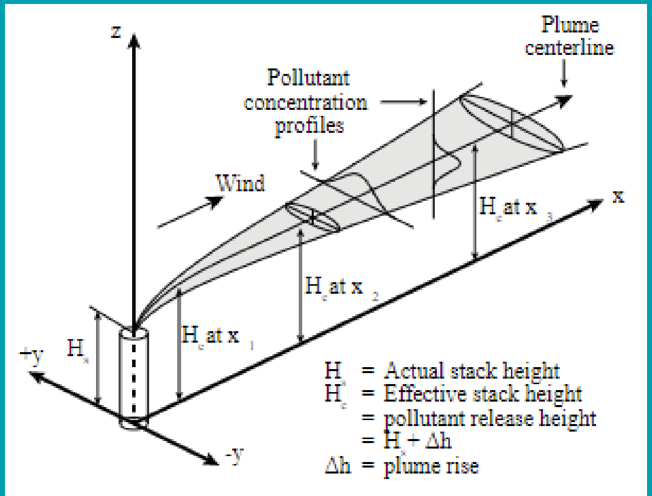
What is AERMOD?

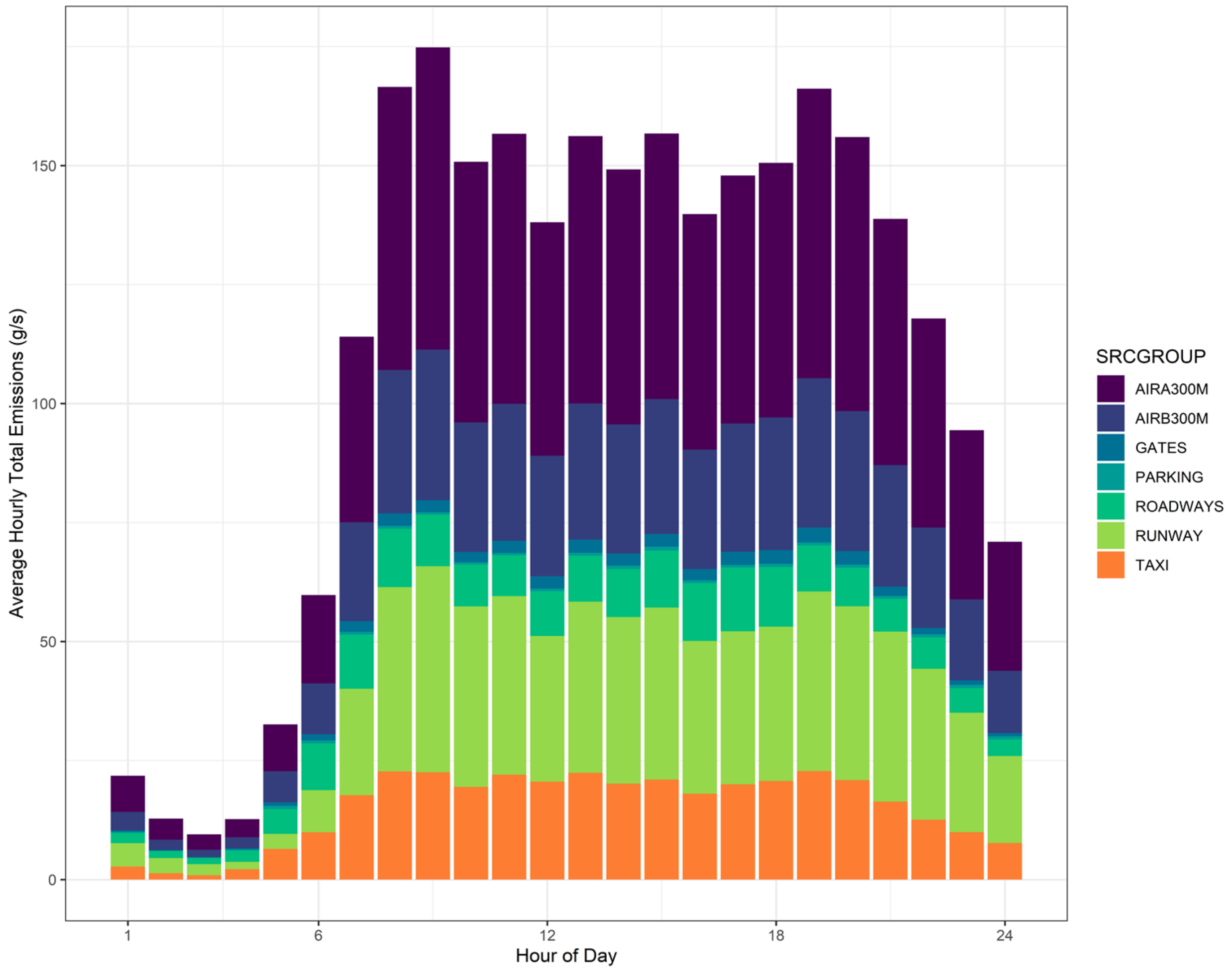
- U.S. EPA promulgated AERMOD in 2005 and is the preferred regulatory model for most applications and is required under the Clean Air Act.
- A steady-state Gaussian model which estimates concentrations by simulating an emission plume's dispersion in the lateral and vertical directions.
- Dispersion accounts for meteorological conditions, surface characteristics, and obstacles influencing the plume's movement & dispersion downwind.



OBJECTIVE:

Evaluate NO → NO_2 Chemistry Options in AERMOD at an Airport

Aviation Environmental Design Tool (AEDT) Airport Estimated NO_x Emission Rates Averaged by Hour of Day for Year Simulation



Overview of Model Input

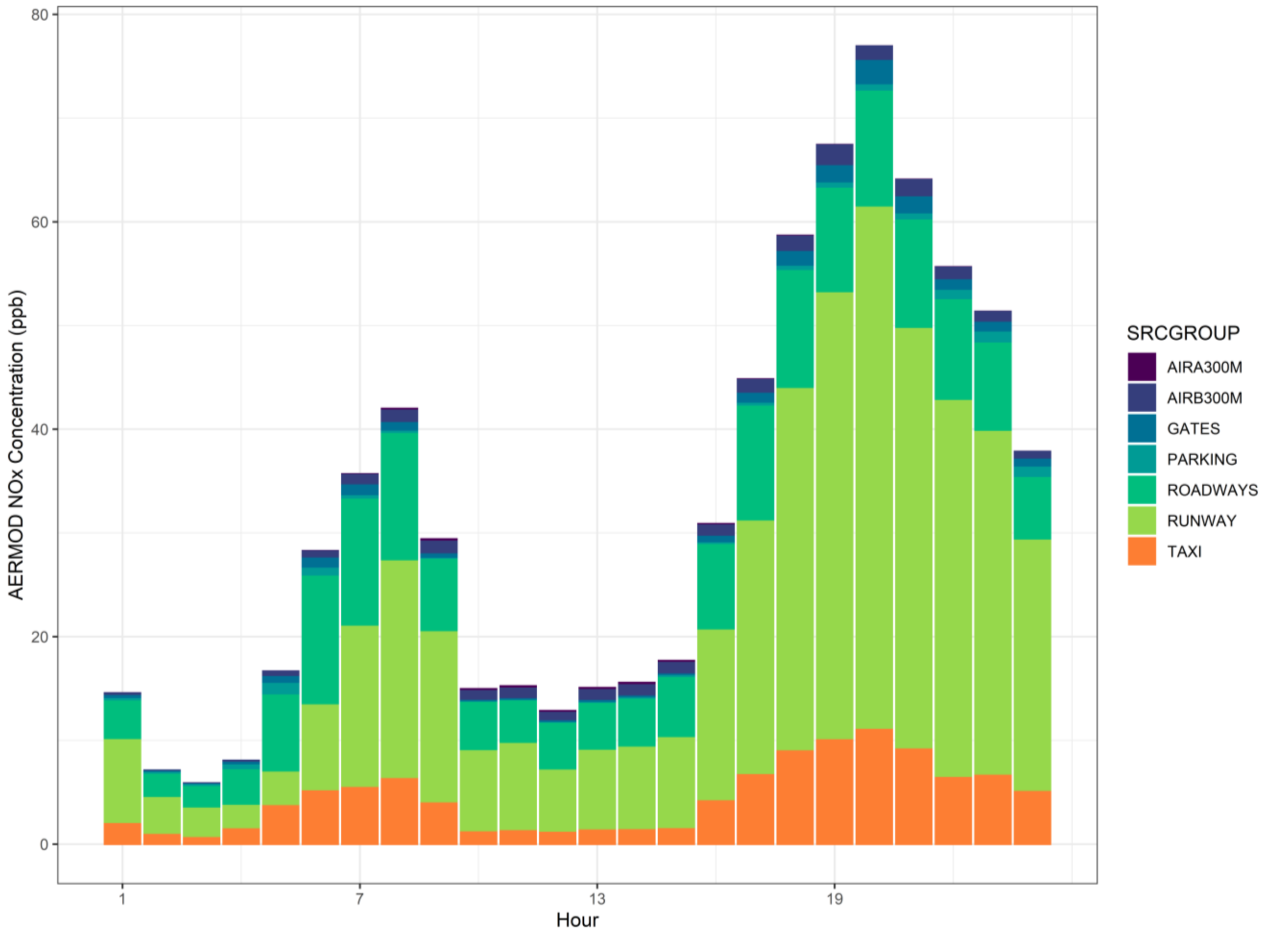
- 1-year model simulation with hourly output
- One Monitor Location near source area located 500 m from airport boundary
- On-site Meteorological data measured at airport
- Airport Sources estimated using AEDT modeled as POINT, AREA, or AREAPOLY
  - Aircraft (separate for: take-off and landing/at height), Roadways, Gates, Runways, Taxiways, Parking, Static Sources
  - Only sources related to airport operation were included

Aviation Environmental Design Tool (AEDT) airport estimated NO_x emission rates

Sources	Source Type	Number of Sources	NO_2 Ratio For Chemistry Methods	Average Emissions (g/sec)	Total Emissions (g/year)	Percent of Total Emissions
Parking Facilities	AREAPOLY	88	0.1	0.54	4.7E+03	0%
Gates	AREAPOLY	9	0.914	1.86	1.6E+04	2%
Roadways	AREA	3233	0.1	8.06	7.1E+04	7%
Taxiways	AREA	599	0.914	15.05	1.3E+05	13%
Aircraft Emissions from 22 to 302 meters (takeoff and landing) (AIRB300M)	AREA	2449	0.108	20.51	1.8E+05	18%
Runways	AREA	1250	0.108	25.96	2.3E+05	23%
Aircraft Emissions at 619.2 meters (cruising) (AIRA300M)	AREA	1275	0.108	40.30	3.5E+05	35%

Source Contributions

- NO_x was run for each source group individually (no chemistry)
- Only wind directions from the airport to the monitor were included
- Modeled concentrations do not include background source contributions
- Ground level airport related sources have largest impact on monitor concentrations (runway source group)



Next we examined NO_2 Chemistry…

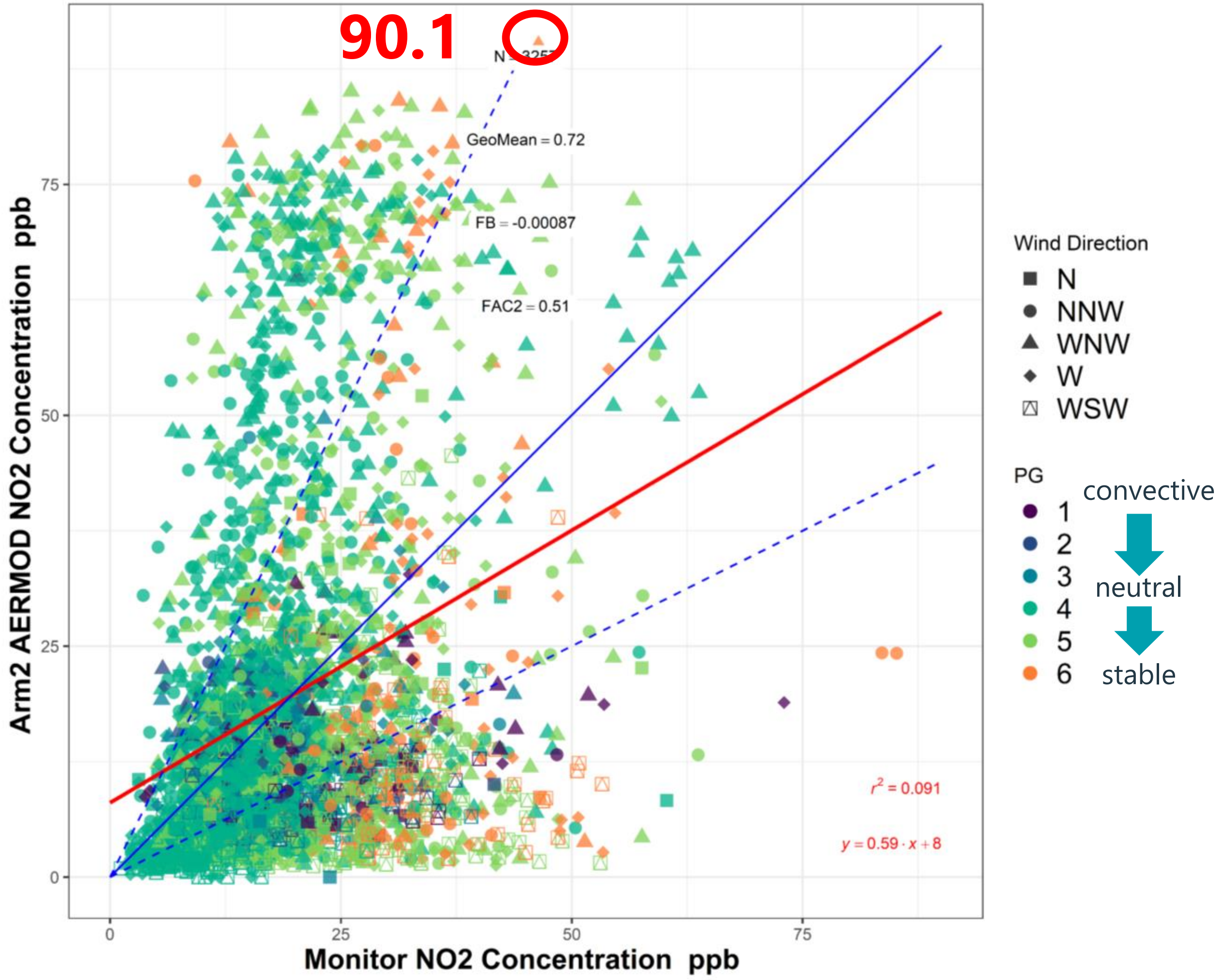
CHEMISTRY METHODS of NO to NO_2

1. Ambient Ratio Method 2 (ARM2)
2. Ozone Limiting Method (OLM)
3. Plume Volume Molar Ratio Method (PVMRM)
4. Travel Time Reaction Method (TTRM)
5. Generic Reaction Set Method (GRSM)

1. Ambient Ratio Method (ARM2)

- Regulatory Option
- NO conversion to NO_2 based on empirical relationship between NO_x and ambient NO_2 concentrations
- Ratio is user-defined, based on source specific information
- Modeled concentrations do not include background source contributions

Podrez, M. 2015. An Update to the Ambient Ratio Method for 1-h NO2 Air Quality Standards Dispersion Modeling. Atmospheric Environment, 103: 163–170.

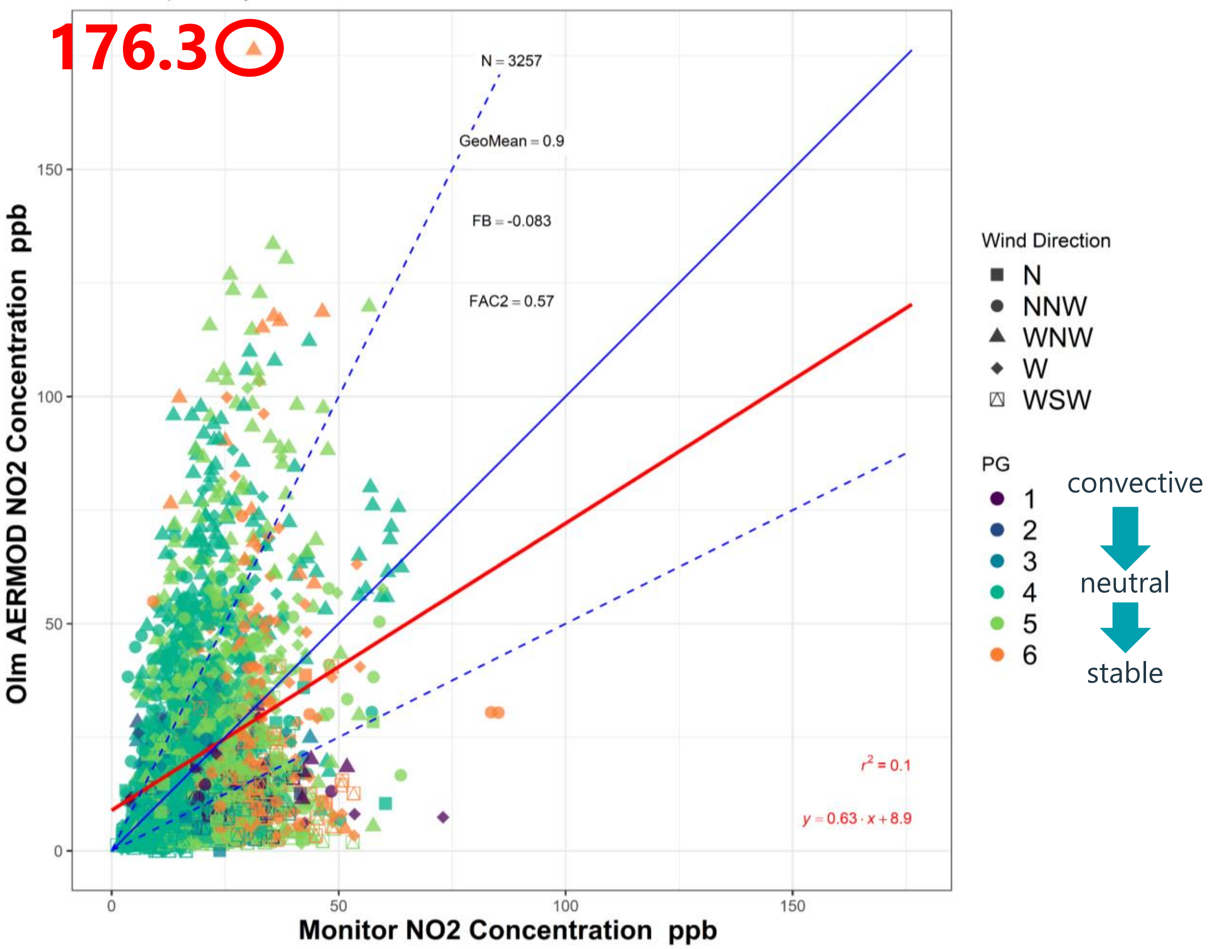


Required Information to Run:

- Minimum Ambient Ratio NO_2/NO_x (0.186)
- Maximum Ambient Ratio NO_2/NO_x (0.717)

2. Ozone Limiting Method (OLM)

- Regulatory Option
- NO conversion to NO_2 by:
  1. Direct NO2 tracked independently
  2. Direct NO converted to NO2 based on ozone levels
  3. Conversion based on ozone concentrations on mixing ratio basis
- Modeled concentrations do not include background source contributions



Required Information to Run:

- Background ozone concentration
- NO_2 /NO_x in-stack ratio

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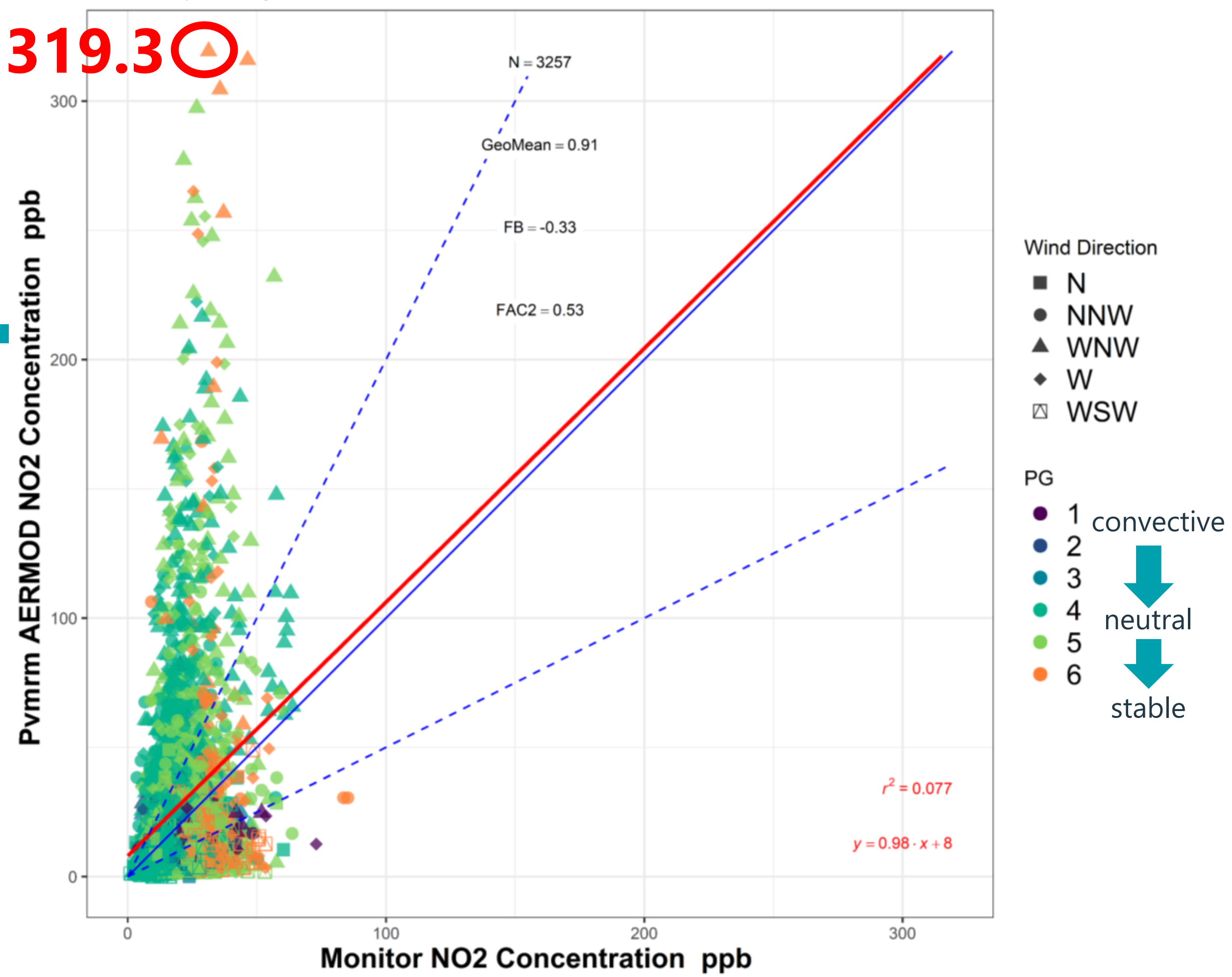
Cole, H.S. and J.E. Summerhays, 1979. A Review of Techniques Available for Estimation of ShortTerm NO2 Concentrations. Journal of the Air Pollution Control Association, 29(8): 812–817

3. Plume Volume Molar Ratio Method (PVMRM)

- Regulatory Option
- NO conversion to NO_2 by:
  1. Direct NO2 tracked independently
  2. Direct NO converted to NO2 based on ozone levels
  3. PVMRM determines conversion rate of NO to NO_2 based on volume of ozone within plume between source and receptor
- Modeled concentrations do not include background source contributions

Hanrahan, P.L., 1999. The Polar Volume Polar Ratio Method for Determining NO2/NOX Ratios in Modeling—Part I: Methodology. Journal of the Air & Waste Management Association, 49: 1324–1331.



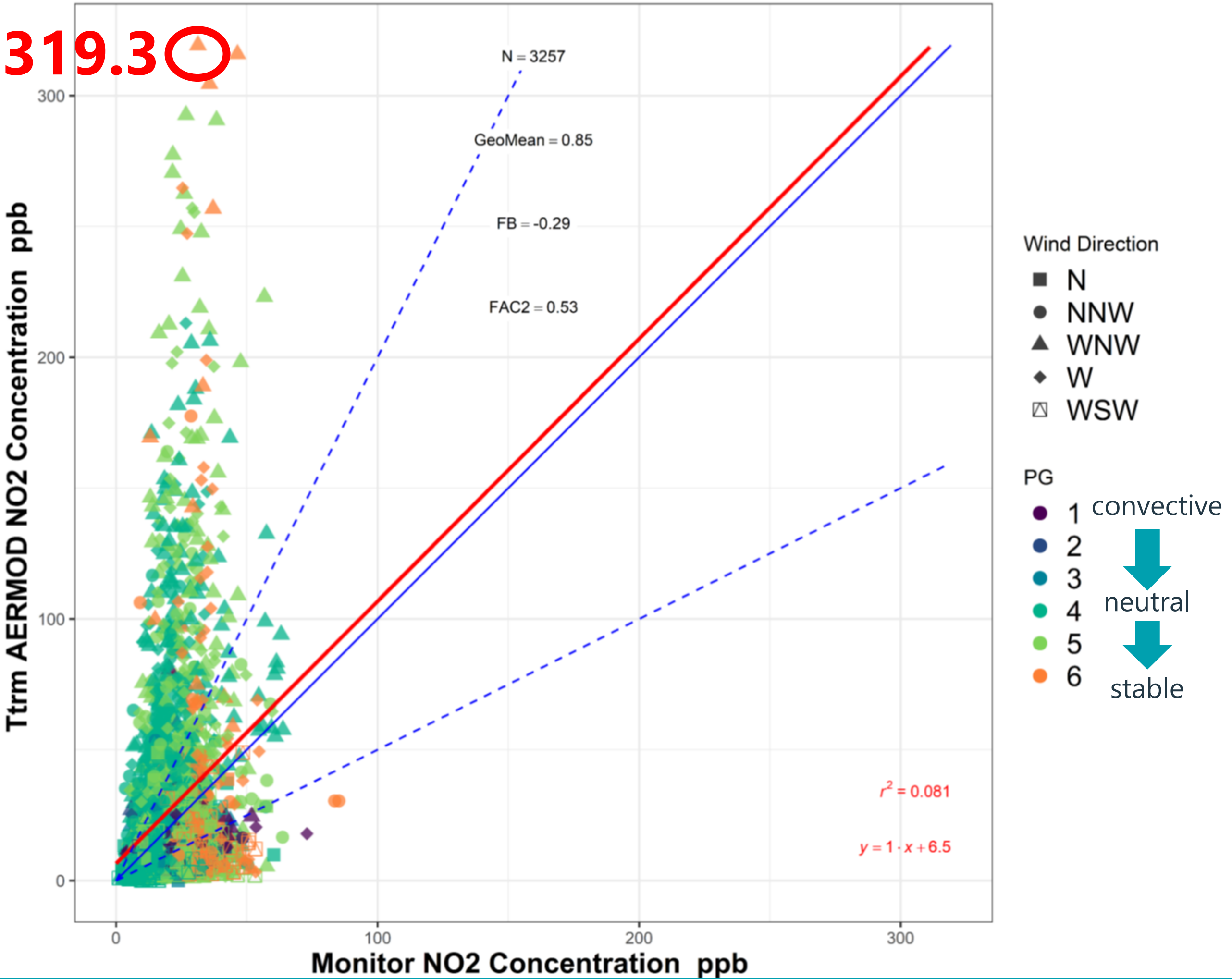
Required Information to Run:

- Background ozone concentration
- NO_2/NO_x in-stack ratio

4. Travel Time Reaction Method (TTRM)

- Non-Regulatory Option (ALPHA)
- NO conversion to NO_2 by:
  1. Direct NO2 tracked independently
  2. Direct NO converted to NO2 based on ozone levels
  3. Ozone reaction limited based on travel time between source and receptor (less conversion close to source, within 300-1000m)
- Modeled concentrations do not include background source contributions

Carruthers, D.J., Stocker, J.R., Ellis, A., Seaton, M.D. and Smith, S.E. (2017). Evaluation of explicit NOX chemistry method in AERMOD. Journal of the Air & Waste Management Association, 67(6), pp.702- 712

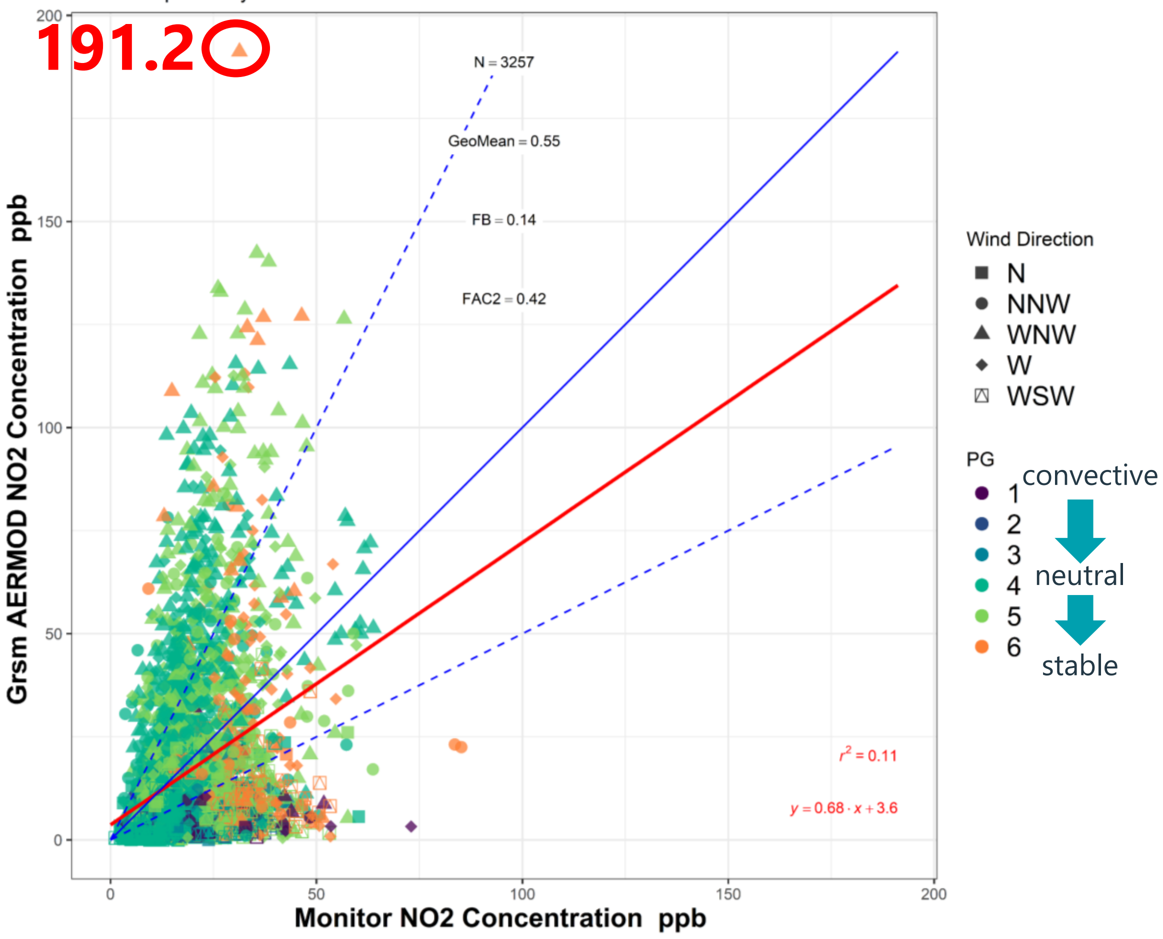


Required Information to Run:
- Background ozone concentration
- NO_2/NO_x in-stack ratio

5. Generic Reaction Set Method (GRSM)

- Non-Regulatory Option
- Computes NO to NO_2 based on equilibrium chemistry between NO, NO_2, and the reaction with ozone
- Modeled concentrations do not include background source contributions

Carruthers, D.J., Stocker, J.R., Ellis, A., Seaton, M.D. and Smith, S.E. (2017). Evaluation of an explicit NOX chemistry method in AERMOD. Journal of the Air & Waste Management Association, 67(6), pp.702- 712.



Required Information to Run:

- Background ozone concentration
- NO_2/NO_x in-stack ratio
- NO_x background concentration

Method Performance Statistics

Statistic	Monitor	PVMRM	ARM2	OLM	TTRM	GRSM
Mean Bias	-	7.7	3.2	**1.7**	**-2.5**	6.5
Fractional Bias	-	-0.3	-0.2	**-0.1**	**0.1**	-0.3
Fractional Bias (top 25)	-	-1.2	**-0.3**	-0.6	-0.7	-1.2
Normalized Mean Square Error	-	2.3	**0.9**	**0.9**	1.2	2.3
Geometric Standard Deviation	-	2.5	2.5	**2.4**	3.1	2.5
Predictions within a factor of two of the observations	-	0.5	0.5	**0.6**	0.4	0.5
Robust Highest Concentration Ratio	-	4.58	**1.11**	1.98	2.02	4.82
Mean Concentration (ppb)	**19.6**	26.9	**19.4**	21.1	25.8	16.9
Max Concentration (ppb)	**85.2**	319.3	**90.1**	176.3	319.3	191.2
Linear Regression Slope	**-**	**1.0**	0.6	0.6	0.7	**1.0**
R^2	-	0.08	0.09	0.10	**0.11**	0.08

Other Considerations

- This study was a sensitivity analysis for the five chemistry methods in AERMOD
- Additional work investigated changes to source parameters, which lead to much greater reductions on NOx concentrations. Changes included:
  - Release Height
  - Source Type
  - Source width
  - Initial Vertical Dispersion (σ_{z0})
- Future evaluations at other airports are planned

Upcoming Publication:

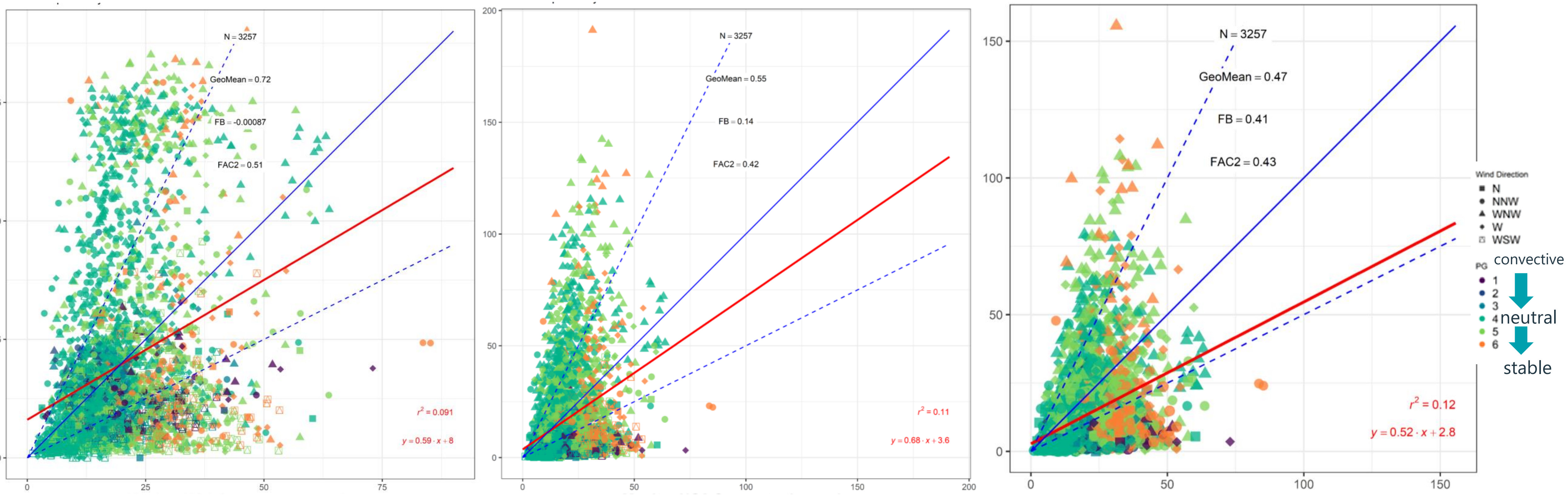
Characterization of Aircraft Emissions for Aviation Environmental Design Tool (AEDT) and American Meteorological Society and Environmental Protection Agency Regulatory Model (AERMOD) for Estimating Airport Impacts

By: Michelle G. Snyder PhD, Melissa M. Buechlein P.E., and Chris Owen, PhD

Conclusions

ARM2 | GRSM | GRSM + LRPR

AERMOD NO_2 Concentration (ppb)



Monitor NO_2 Concentration (ppb)

Please email questions to melisssa.buechlein@woodplc.com

ADDITIONAL SLIDES

AERMOD Pre-processors

- Surface characterization
- Input into AERMET

- Meteorological data pre-processor
- Incorporates:
  - Planetary Boundary Layer Turbulence
  - Scaling concepts

- Terrain data pre-processor
- Incorporates complex terrain using USGS Digital Elevation Data

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