Modeling Ozone in the Eastern U.S. using a Fuel-Based Mobile Source Emissions Inventory

Brian C. McDonald, Ph.D.

CU/NOAA: Stuart McKeen, Yuyan Cui, Ravan Ahmadov, Si-Wan Kim, Gregory Frost, Michael Trainer

CIRES
Cooperative Institute for Research in Environmental Sciences

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Recent Studies Suggest Overestimate in U.S. NO_x Emissions

- **DISCOVER-AQ (2011):** Mobile source NO_x high by **51-70%** in the National Emissions Inventory (NEI) 2011 [Anderson et al. *Atmos. Env. 2014*]
- **UBWOS (2012-13):** Oil & gas NO_x in the Uintah Basin, UT high by factor of **~4x** in the NEI [Ahmadov et al. *Atmos. Chem. Phys. 2015*]
- **SEAC^{4}RS (2013):** Industrial and mobile source NO_x high in the NEI, **30-60%** reductions needed [Travis et al., *Atmos. Chem. Phys. 2016*]

Mobile Sources

Industry

Oil & Gas Development

Research Objectives

(1) Assess "Bottom-Up" Mobile Source Emissions

- Focus on NO_x, but CO and VOCs can also be assessed
- Construct fuel-based inventory and compare with EPA MOVES2014

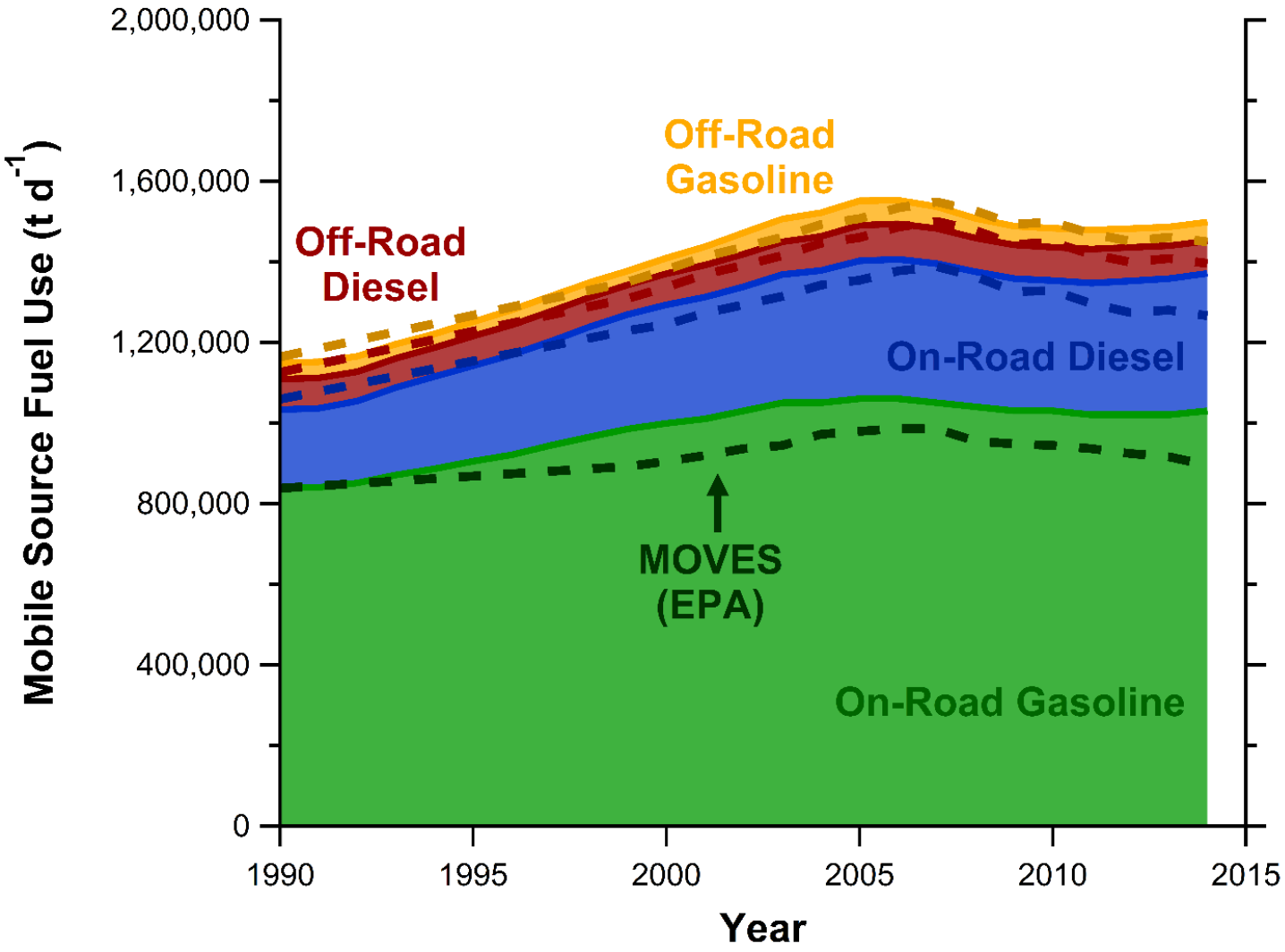
(2) Perform "Top-Down" Model Evaluation

- Evaluate emissions with aircraft- and ground-based measurements

(3) Test sensitivity of ground-level O_3 to mobile source NO_x and biogenic VOC emissions

U.S. Mobile Source Activity (Fuel-Based vs. MOVES)

Emissions = Activity (kg fuel) **x Emission Factor** (g/kg fuel)



Fuel estimates based on FHWA and EIA surveys

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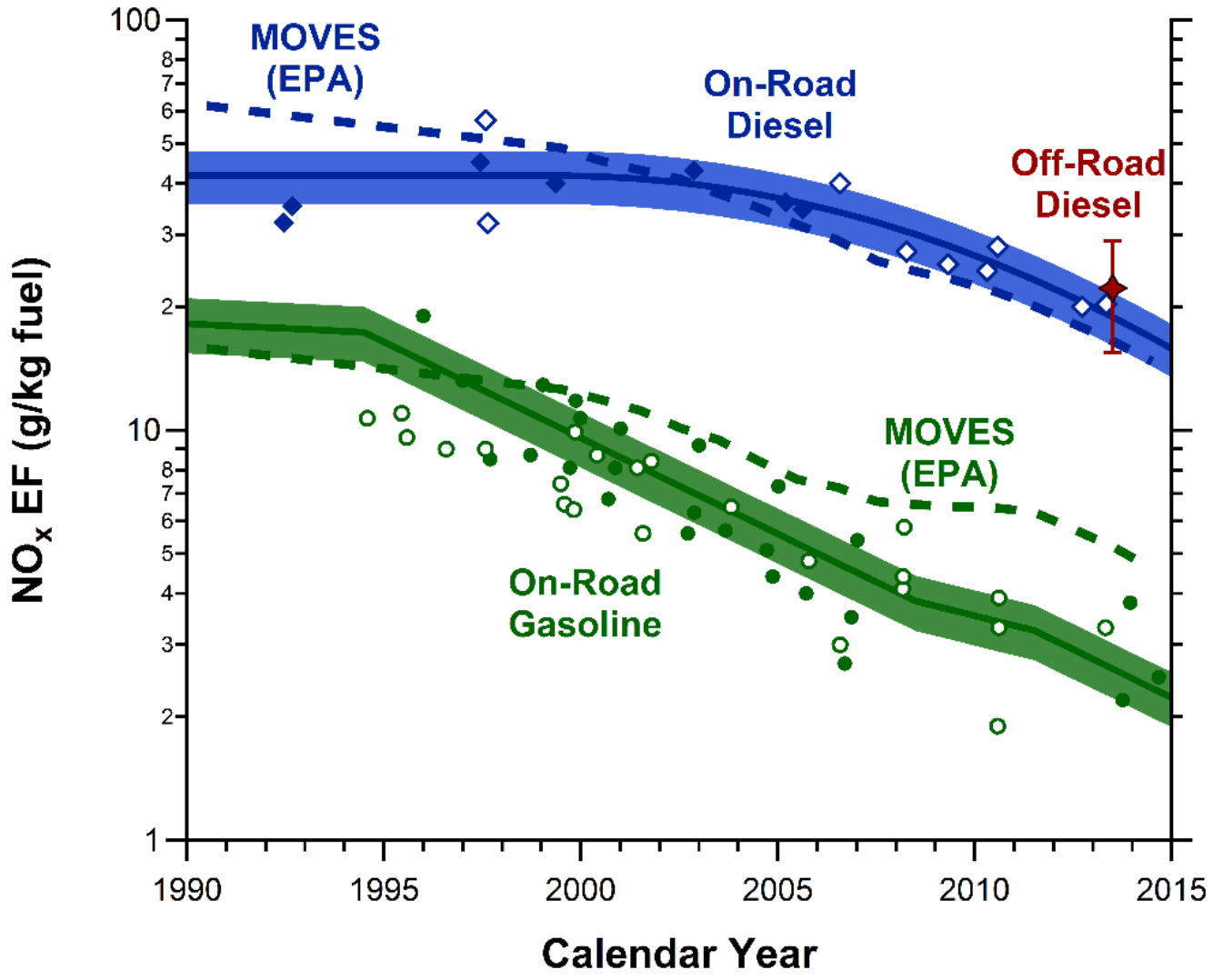
Similar to MOVES2014

Long-Term Trends in On-Road NO_x Emission Factors

Emissions = Activity (kg fuel) **x Emission Factor** (g/kg fuel)

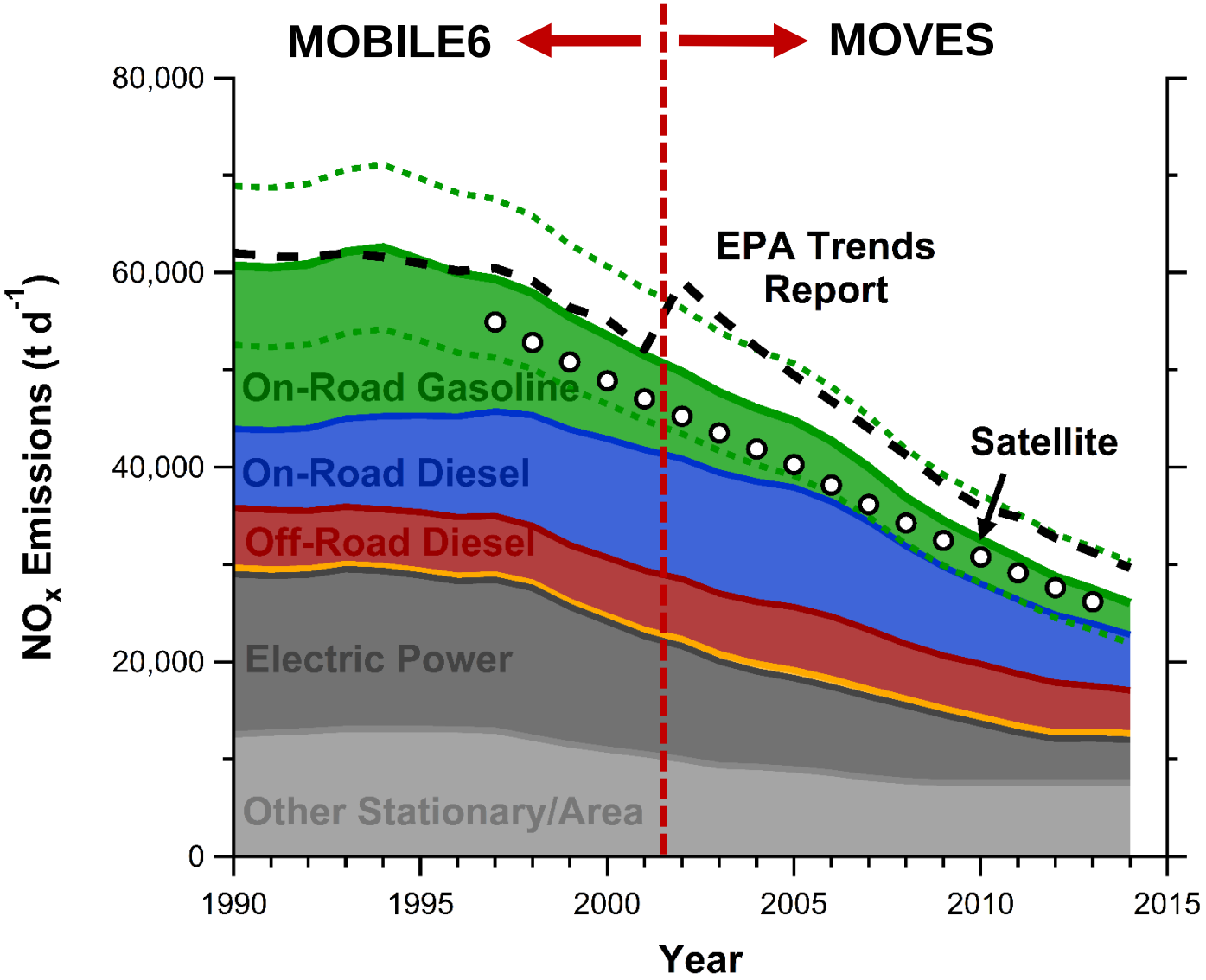


Diesel EF within **~20%**

Gasoline EF high by factor of **~2**

MOVES EF are default values

Long-Term Trends in Total U.S. NO_x Emissions

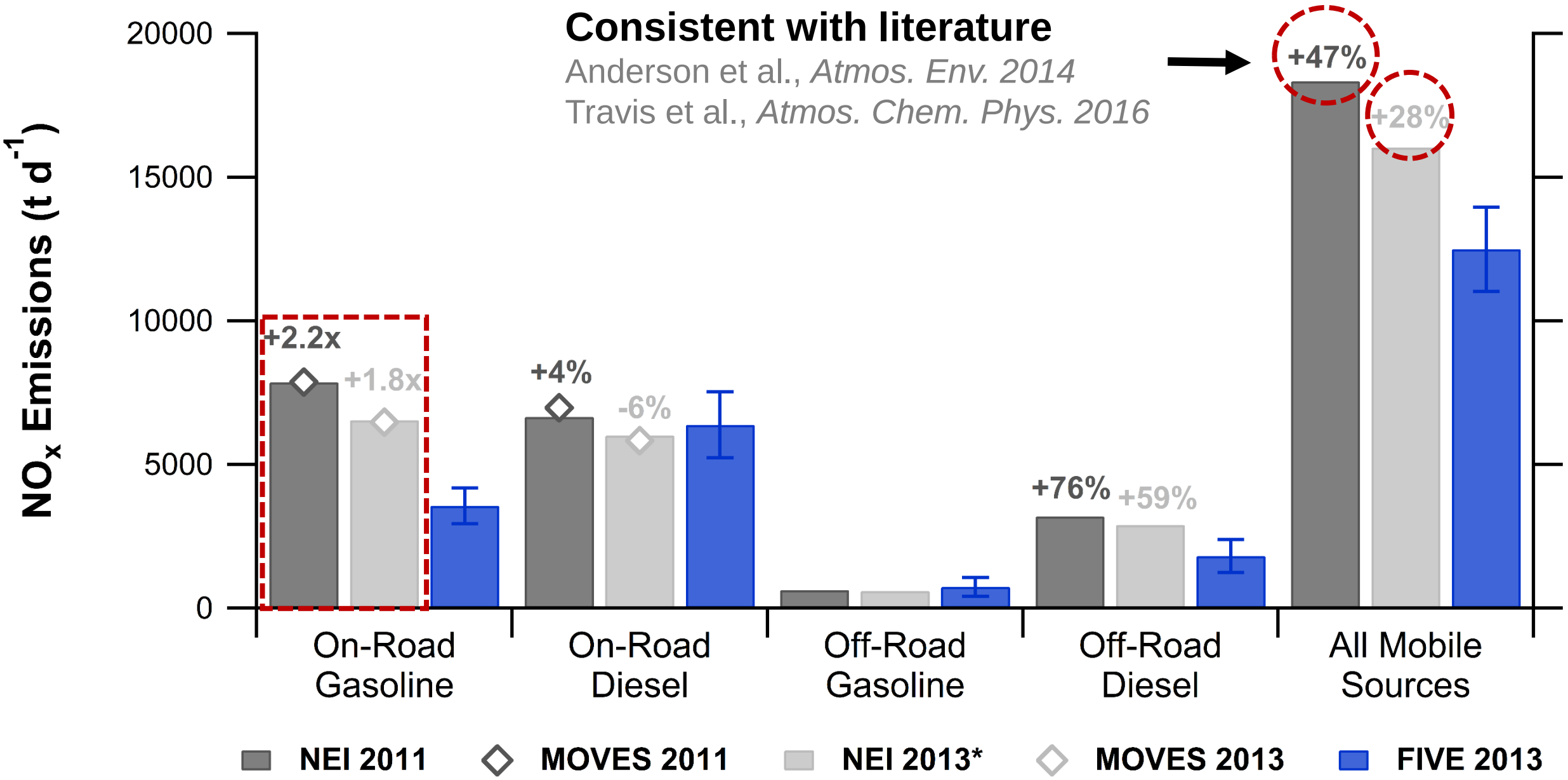


Trend in Fuel-Based Mobile Source Emissions are

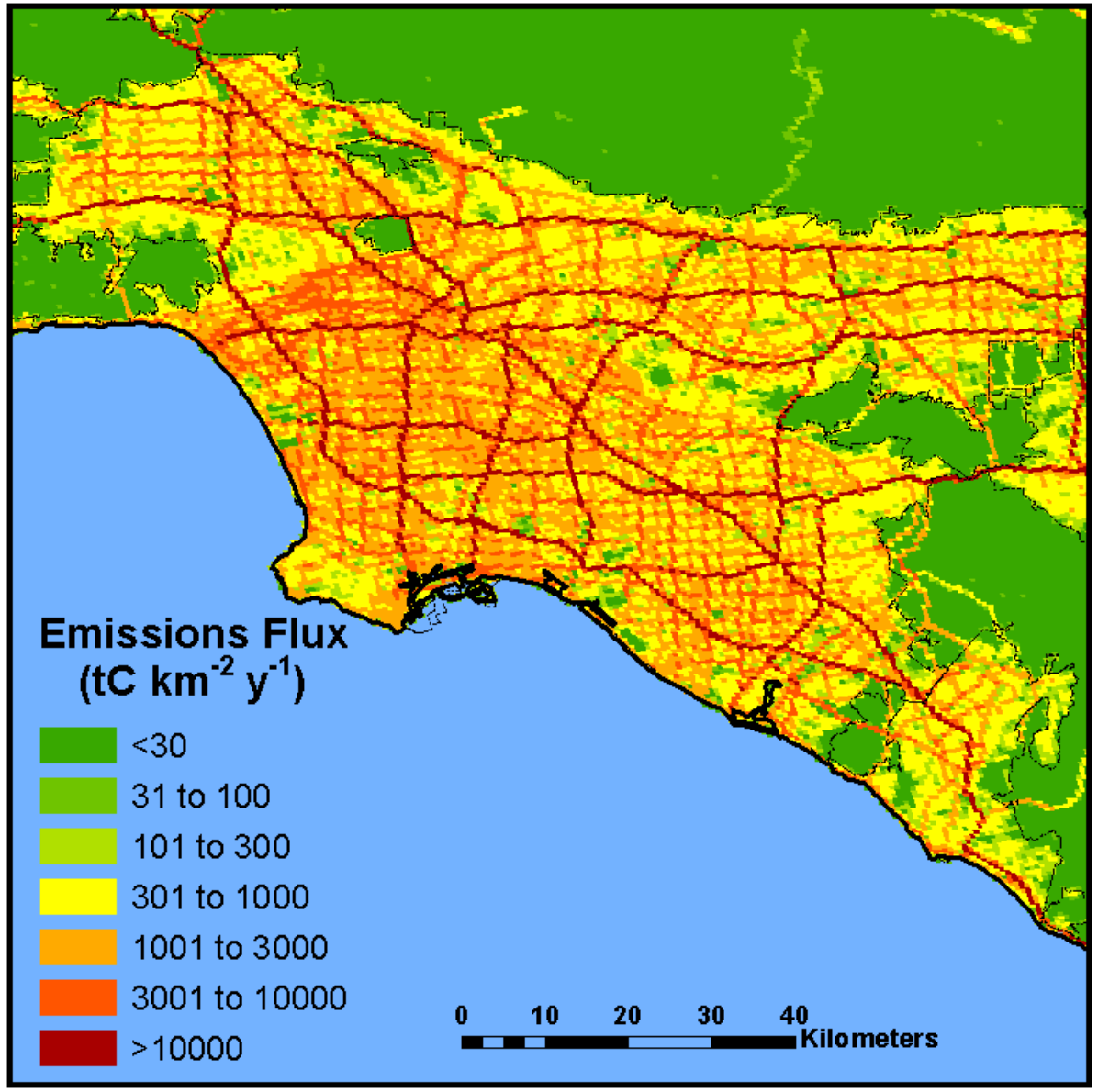
- Similar with MOBILE6
- Similar with MOVES, but offset by ~2 years

Updated from McDonald et al. *J. Geophys. Res.* 2012

U.S. Mobile Source NO_x Emissions



Gridded Fuel-Based Inventory of Vehicle Emissions (FIVE)



State-level taxable gasoline and diesel fuel sales reports

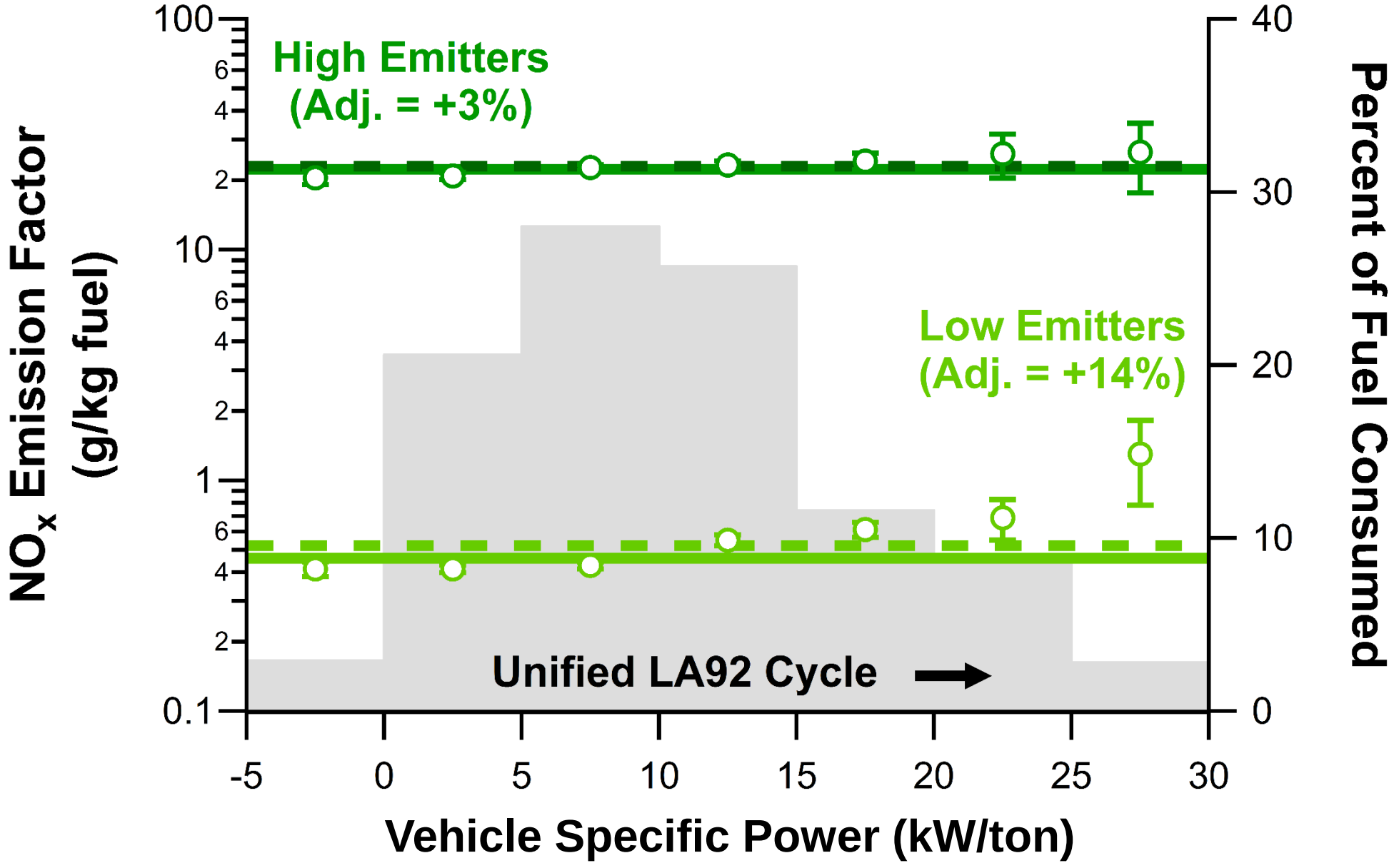
- Public and annual

Map on-road CO_2 emissions

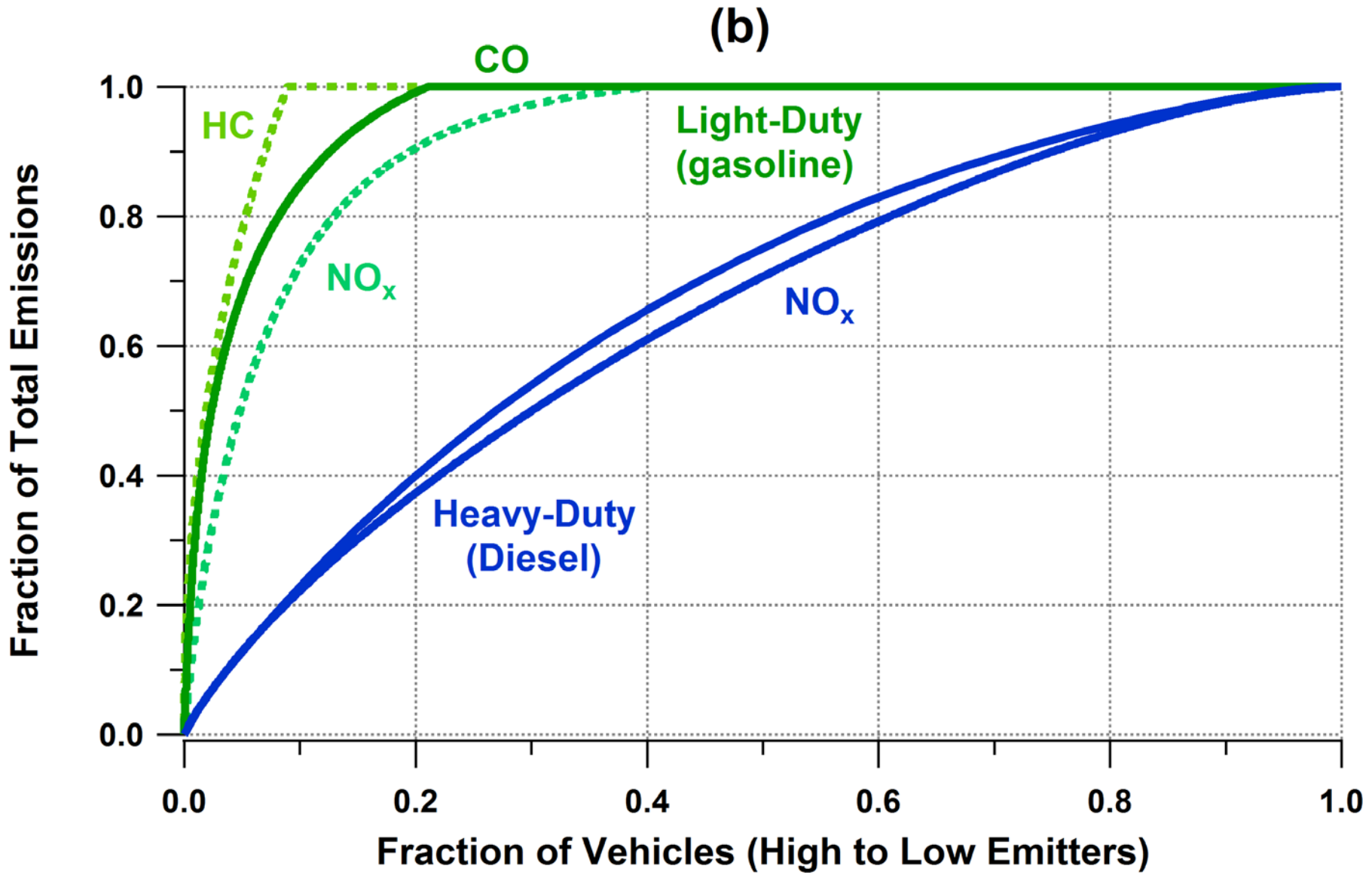
- Using traffic count data
- Basis for scaling co-emitted combustion byproducts

McDonald et al. *J. Geophys. Res.* 2014

Effect of Drive Cycle on Fuel-Based NO_x Emission Factors



High-Emitting Vehicles Dominate Running Exhaust Emissions



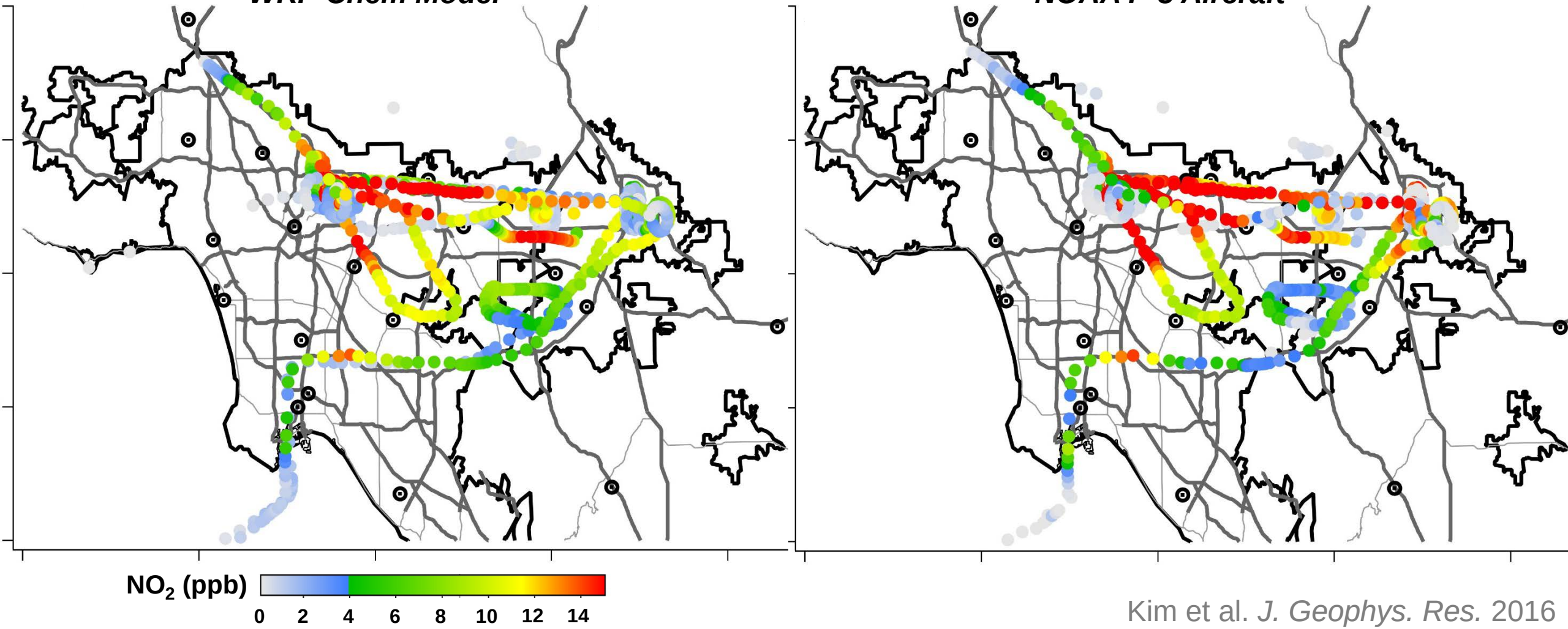
McDonald et al. *Environ. Sci. Technol.* 2013

Fuel-Based Inventory in a Regional Model (Los Angeles 2010)

LA good test case of transportation emissions (**~2/3** of NO_x budget)

WRF-Chem Model

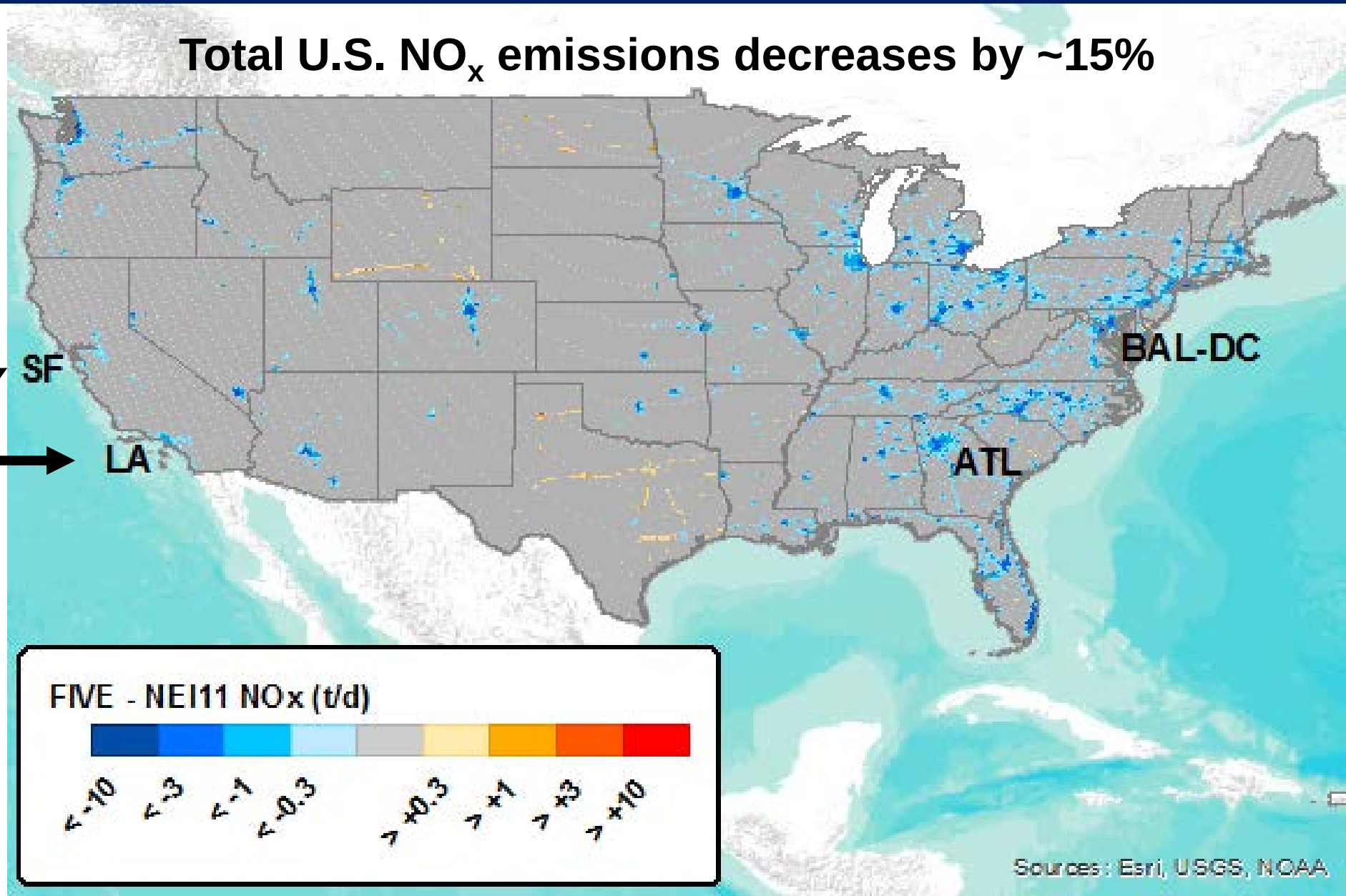
NOAA P-3 Aircraft



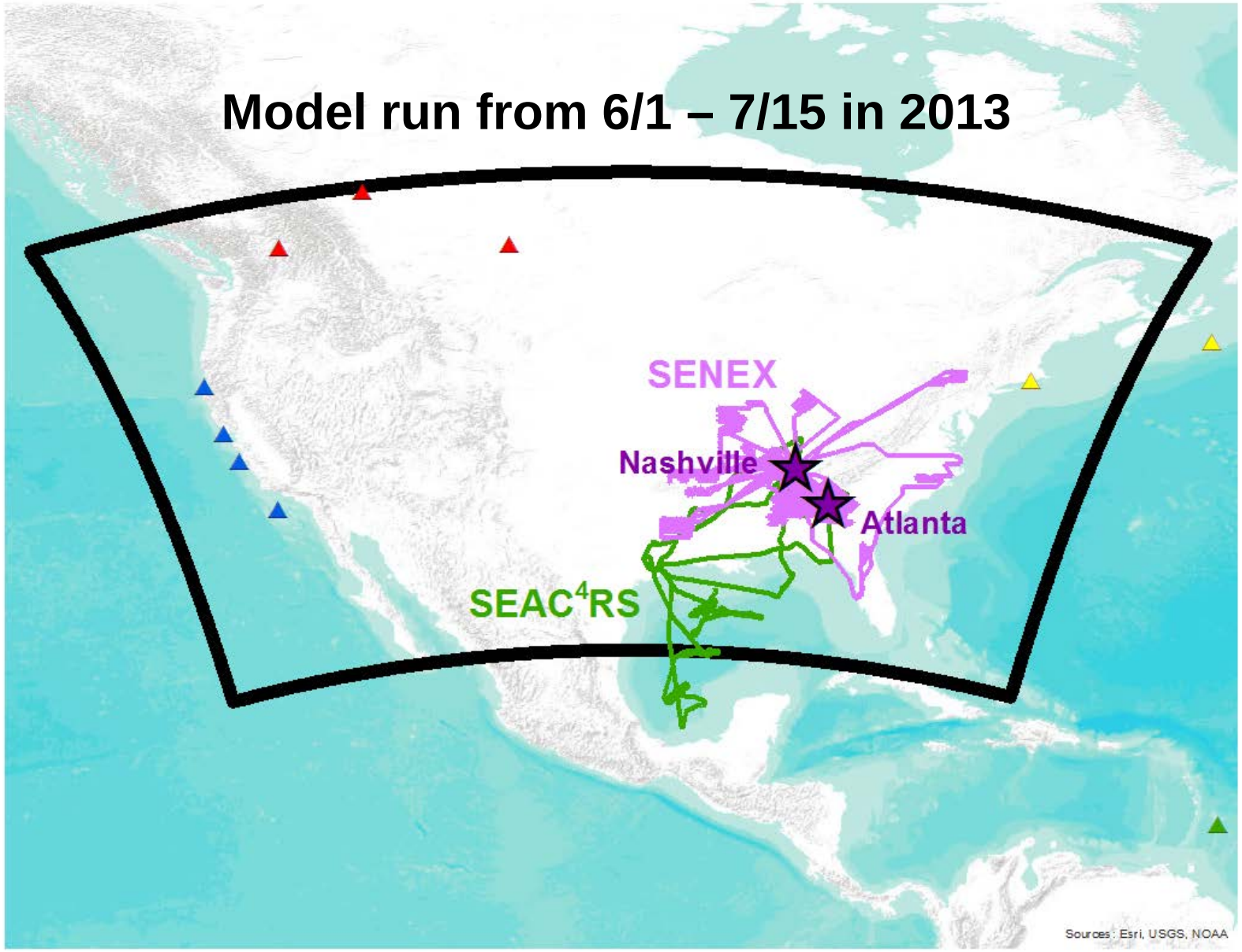
Kim et al. *J. Geophys. Res.* 2016

Expanding FIVE to Continental U.S. and Comparison with NEI

CA emissions relatively unchanged



WRF-Chem Modeling for Southeast Nexus (SENEX) Study



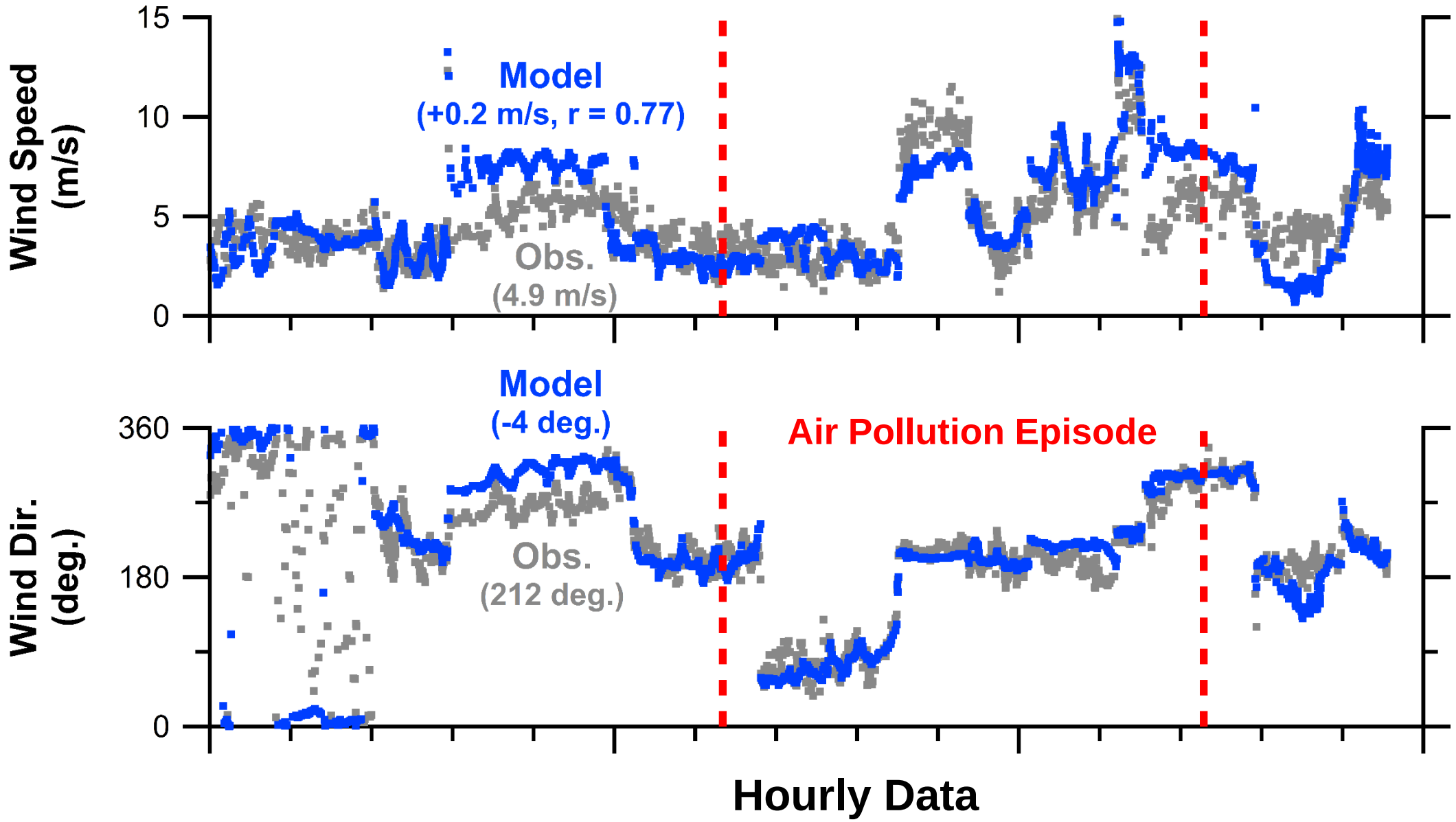
WRF-Chem Model v3.7

- 12 km x 12 km
- 61 vertical layers
- ECMWF-Era-Interim
- RACM Chemistry
- Static Chemical B.C.

Emission Cases:

(i) NEI11 + 1 * BEIS ISO
(ii) NEI11 + 2 * BEIS ISO
(iii) FIVE13 + 1 * BEIS ISO
(iv) FIVE13 + 2 * BEIS ISO

Model Evaluation of Meteorology (vs. Aircraft Data)



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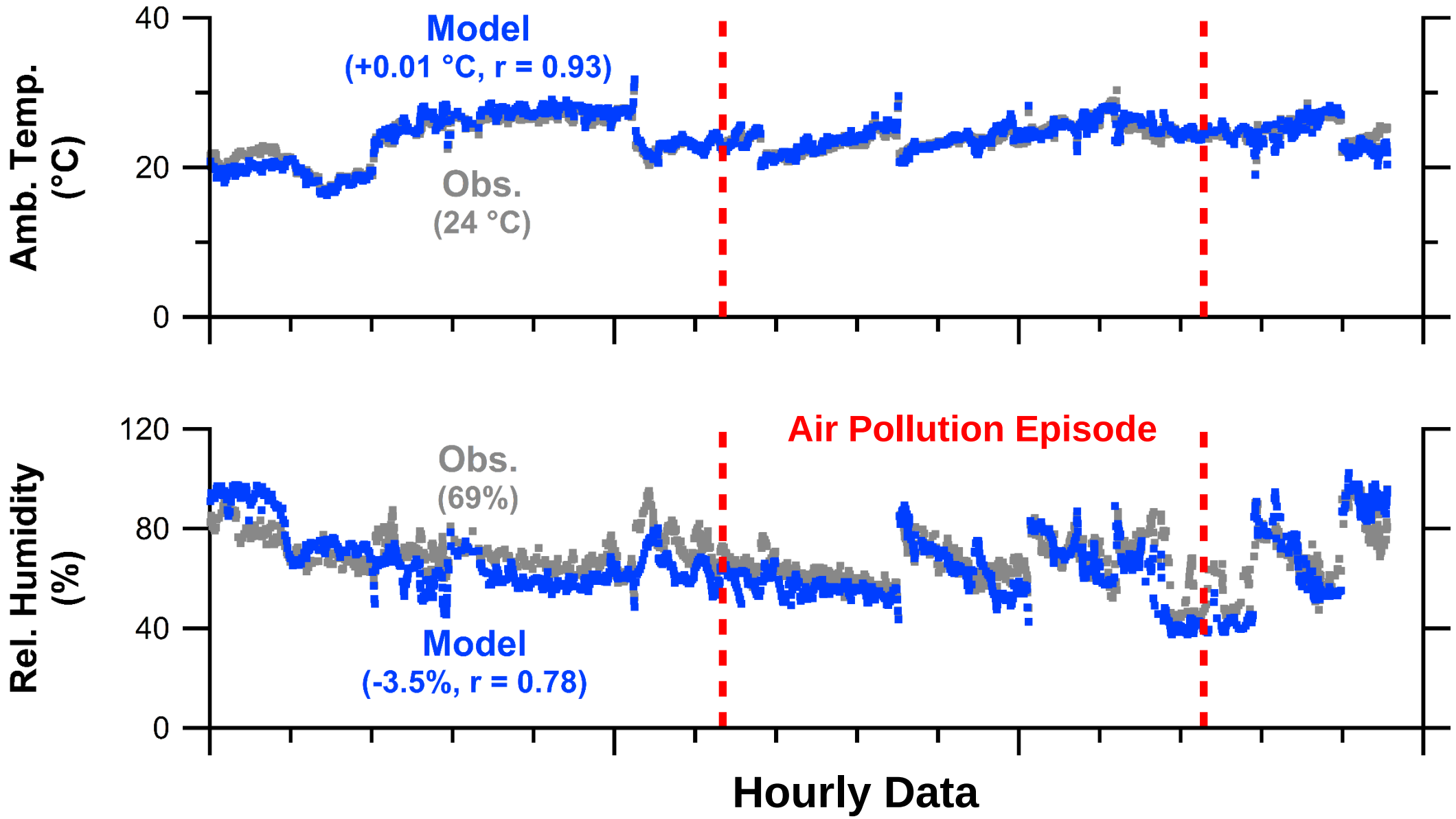


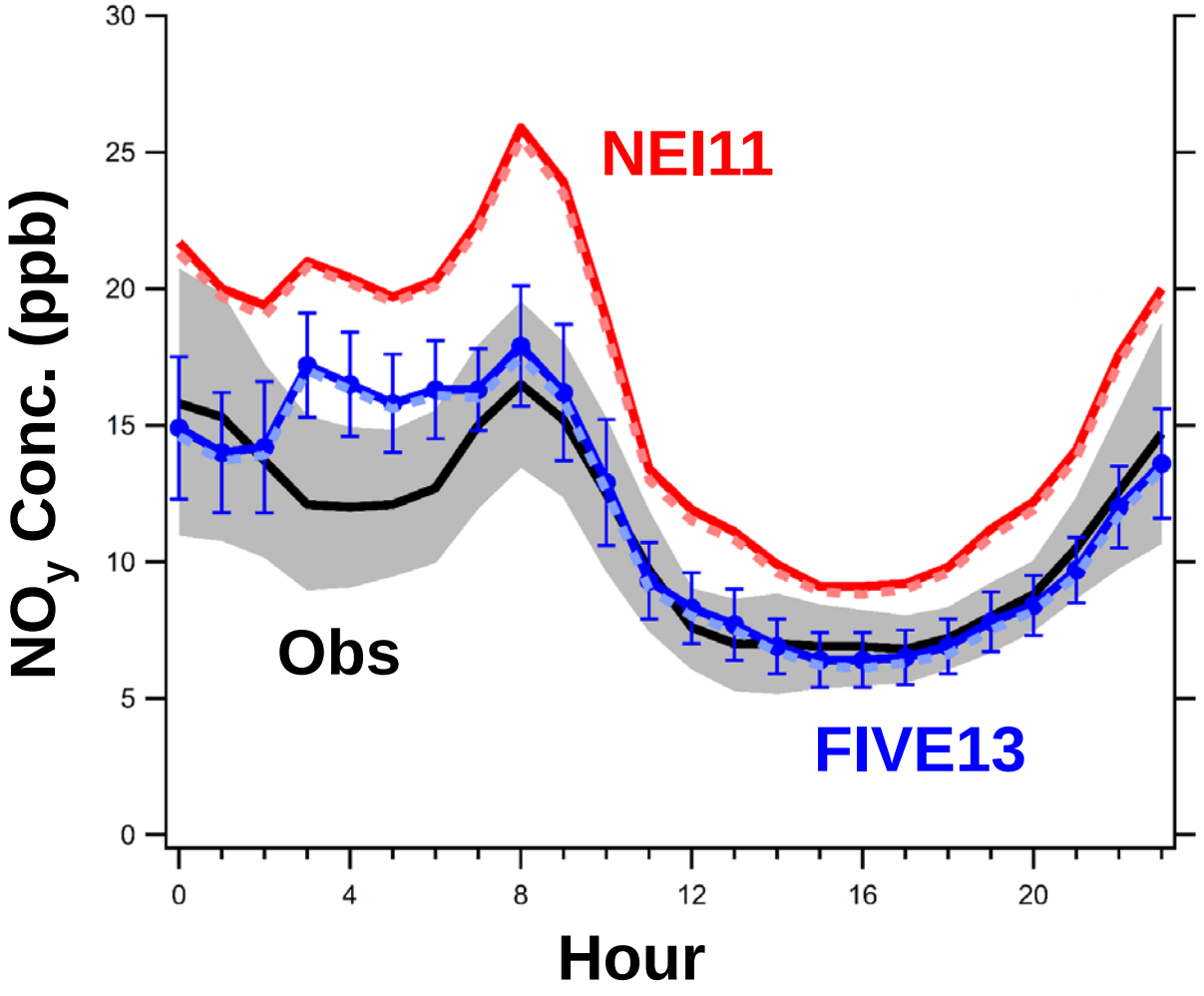
Model Evaluation of NO_y and O_3 across Southeastern U.S.

Emissions Case	NO_y (ppb)	O_3 (ppb)
P-3 Obs.	**2.1**	**47**
(i) NEI11 + 1 * BEIS ISO	**2.9** (+43%)	**56** (+20%)
(ii) NEI11 + 2 * BEIS ISO	**2.8** (+34%)	**54** (+15%)
(iii) FIVE13 + 1 * BEIS ISO	**2.5** (+21%)	**53** (+12%)
(iv) FIVE13 + 2 * BEIS ISO	**2.3** (+13%)	**50** (+6%)

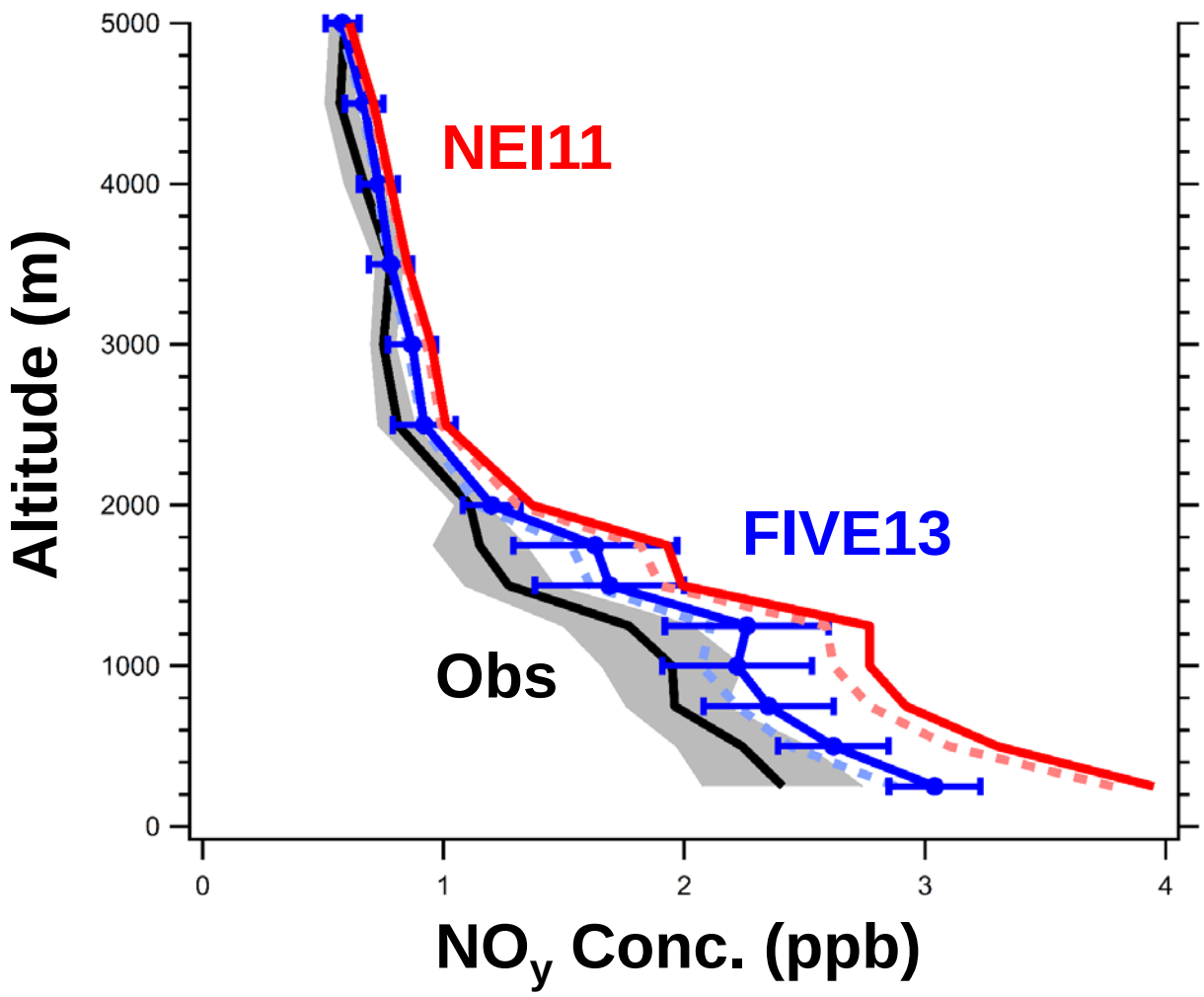
Reducing mobile source NO_x *cannot* fully explain high model NO_y and O_3

Model Evaluation of NO_x Emissions in Urban Plumes

Atlanta (SEARCH site)

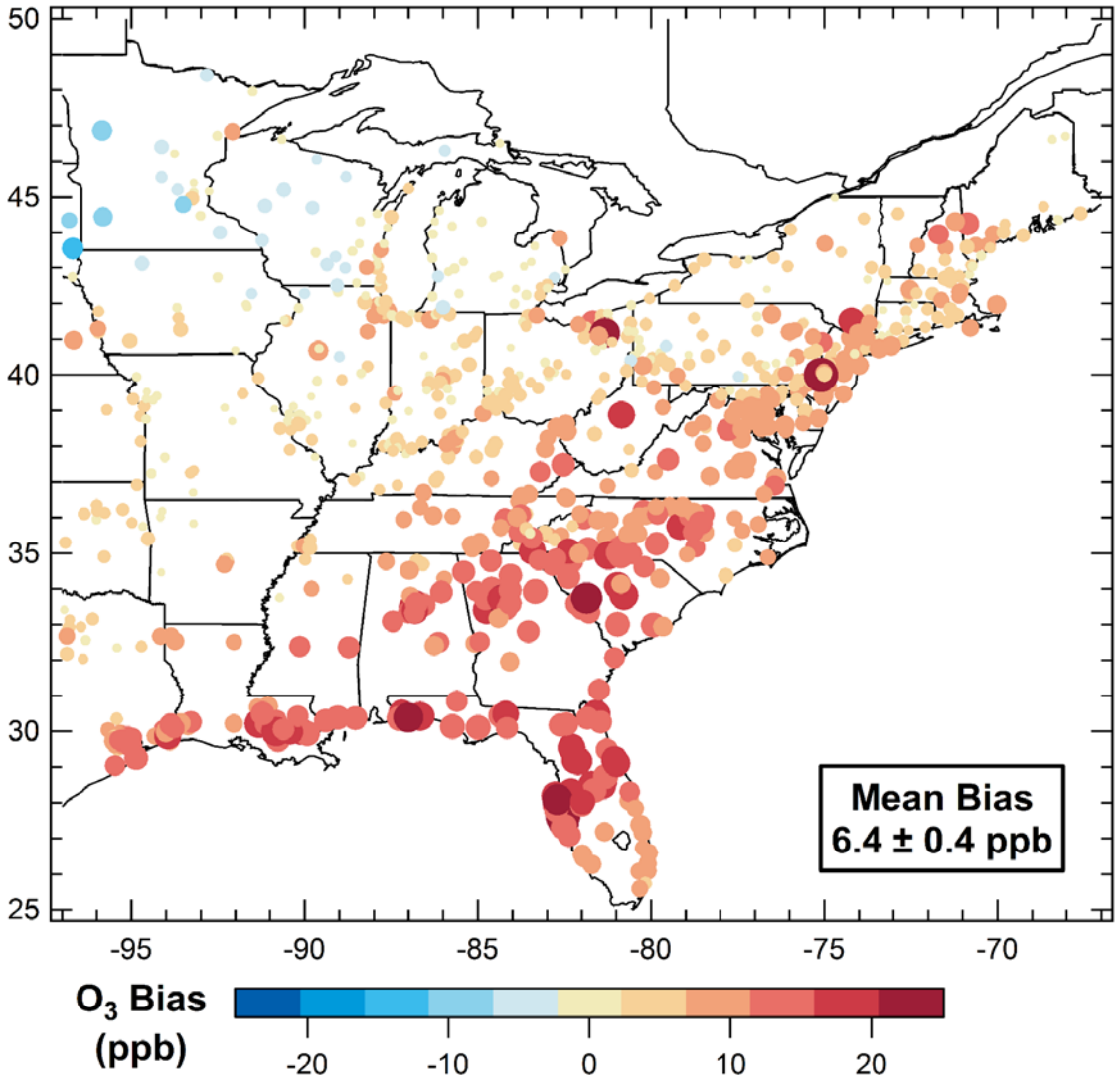


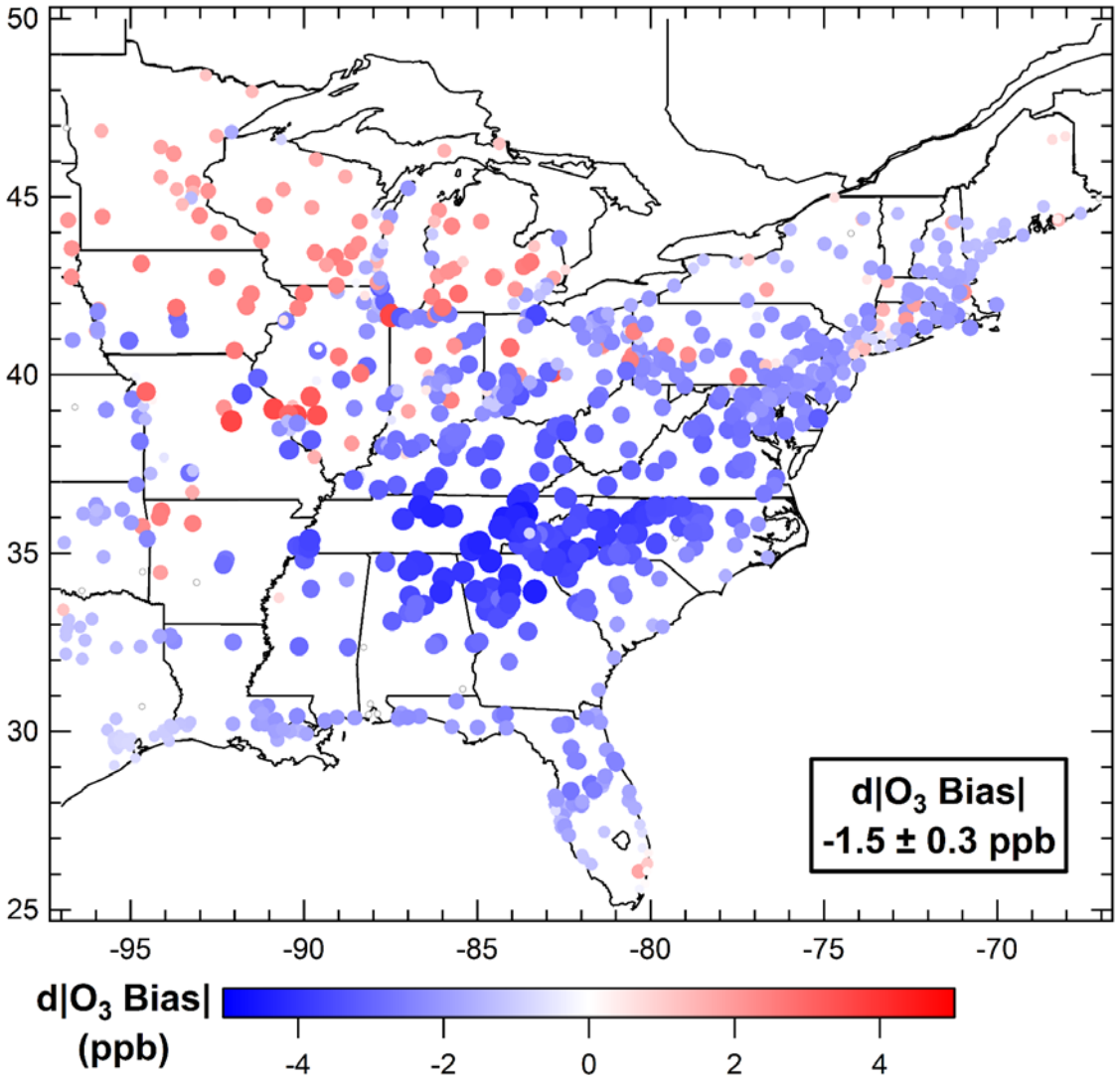
Nashville (P-3 aircraft)



Δ(NEI11 – FIVE13) cases represent ~4 years of vehicle emission reductions

Improvement in Average O_3 from Reducing Mobile Source NO_x



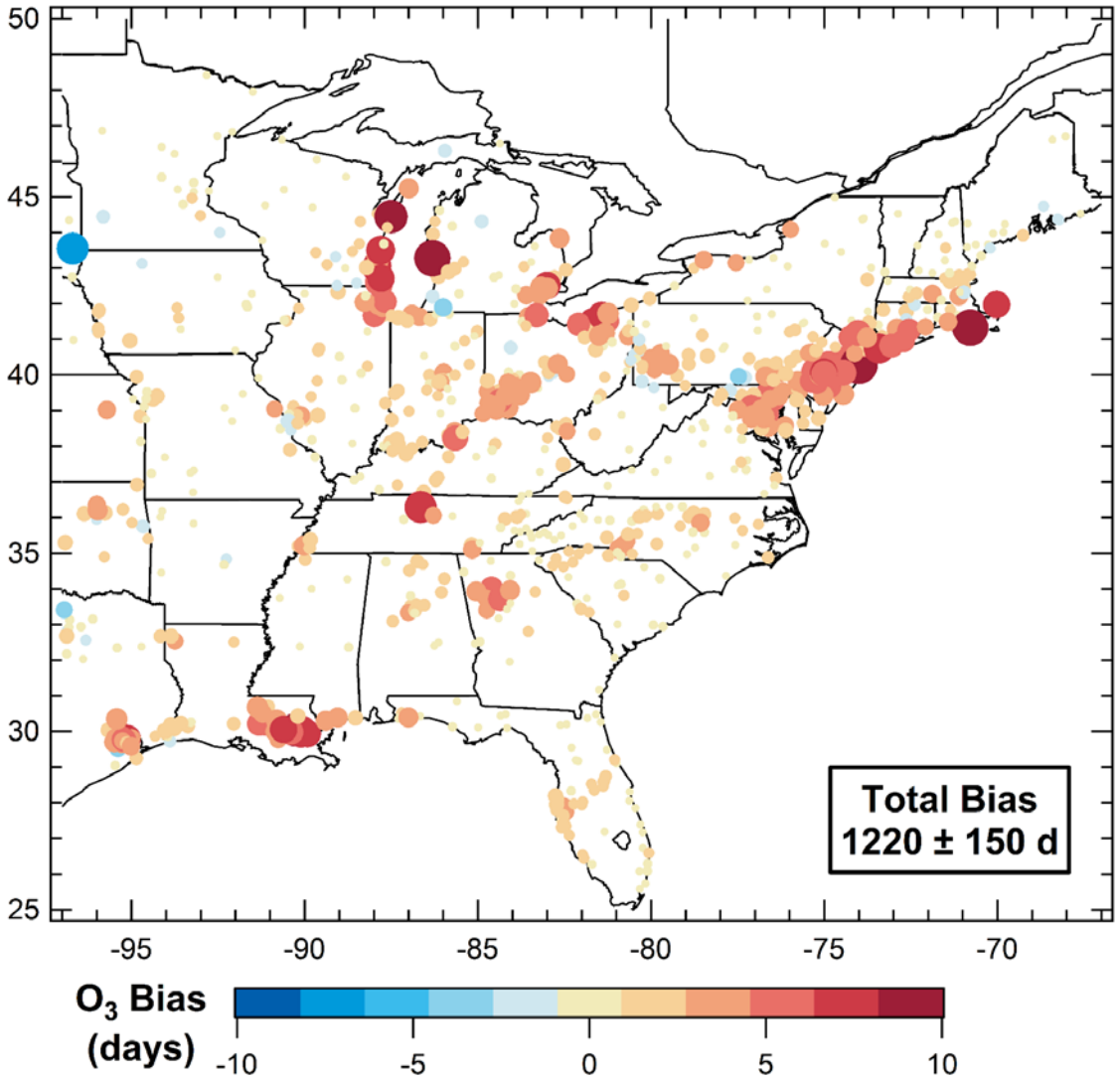


Bias in summer 2013 mean daily 8-h maximum modeled with NEI 2011 vs. AQS data

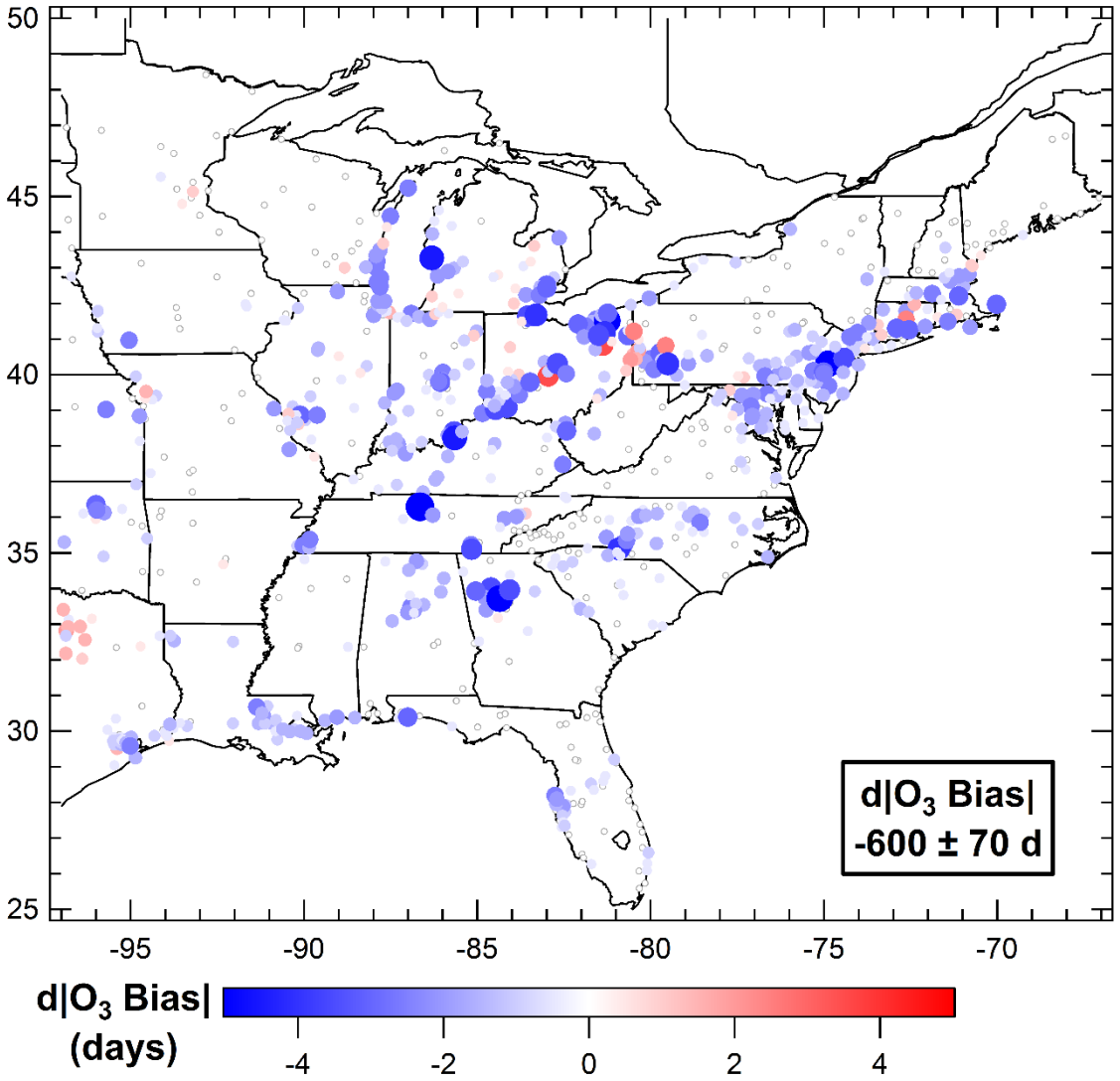
← **FIVE is better**

FIVE is worse →

Ozone Exceedances More Sensitive to Mobile Source NO_x



Bias in summer 2013 O_3 exceedance days (>70 ppb) modeled with NEI 2011 vs. AQS data



← FIVE is better

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Summary

- **NO_x overestimate seen in model, and partially explained by mobile sources**
  - Biggest discrepancies found in the on-road gasoline sector
  - Mobile source reductions in NO_x can explain ~half of model NO_y and O_3 bias
- **In Eastern U.S., ozone days (>70 ppb) sensitive to mobile source NO_x**
  - Test cases simulate vehicle emission reductions over ~4 years