Impacts of COVID-19 Related Shutdown on Onroad and Air Transportation Emissions-related O_3, NO_2 and $PM_{2.5}$ in the U.S. using Sensitivity Modeling Techniques

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All Results preliminary. Please do not cite or quote

Due to COVID-19, 3.6B people were on lockdown globally

Air Pollution declines reported globally

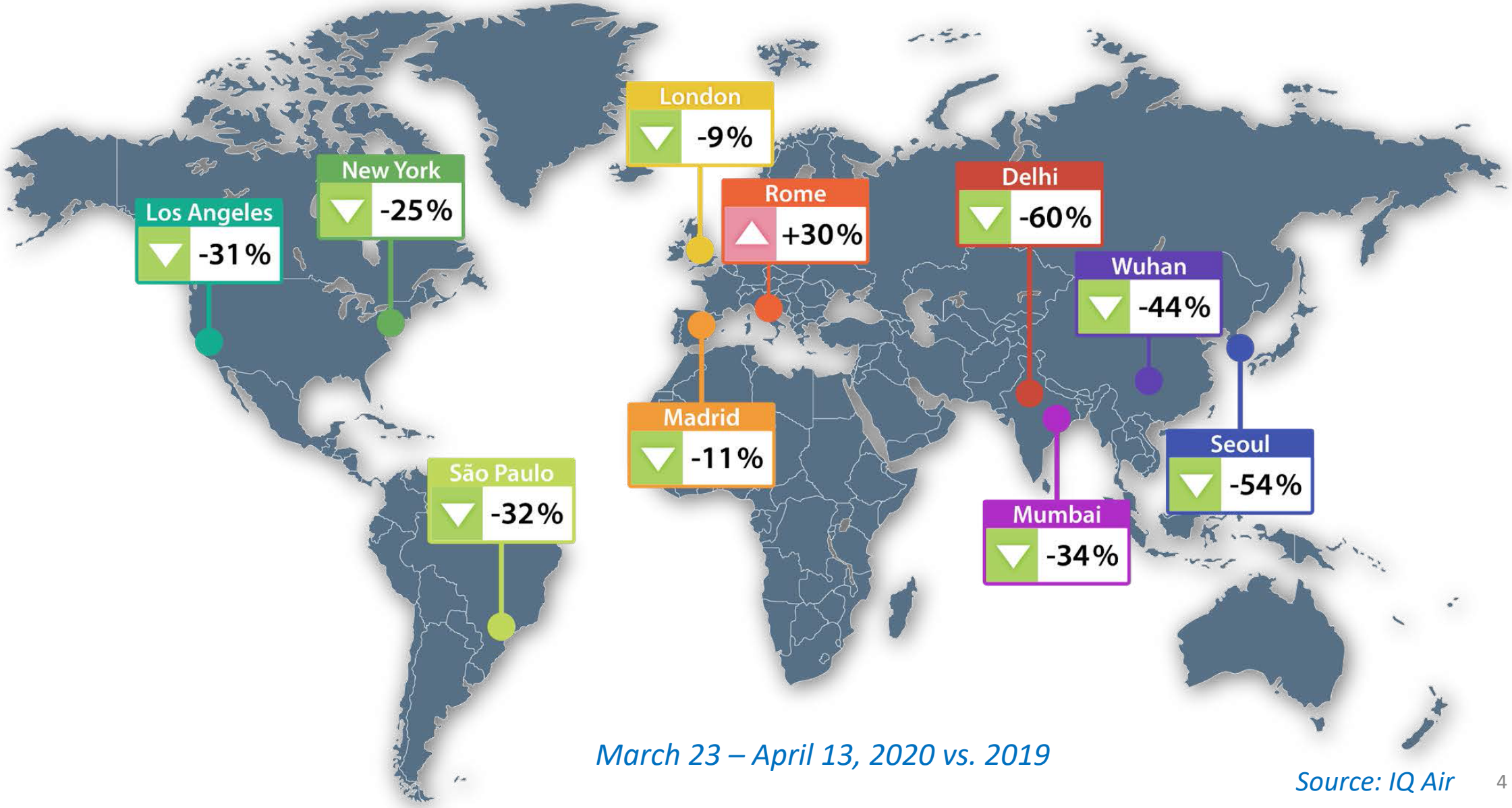
e.g. 1: Himalayas visible from > 100 miles in Punjab, India (after several decades)

Source: The Times

e.g. 2: Snow on San Gabriel Mtn and Blue Skies in Los Angeles (Smog Capital of the World)

Source: Getty Images

Change in $PM_{2.5}$ during Lockdown



March 23 – April 13, 2020 vs. 2019

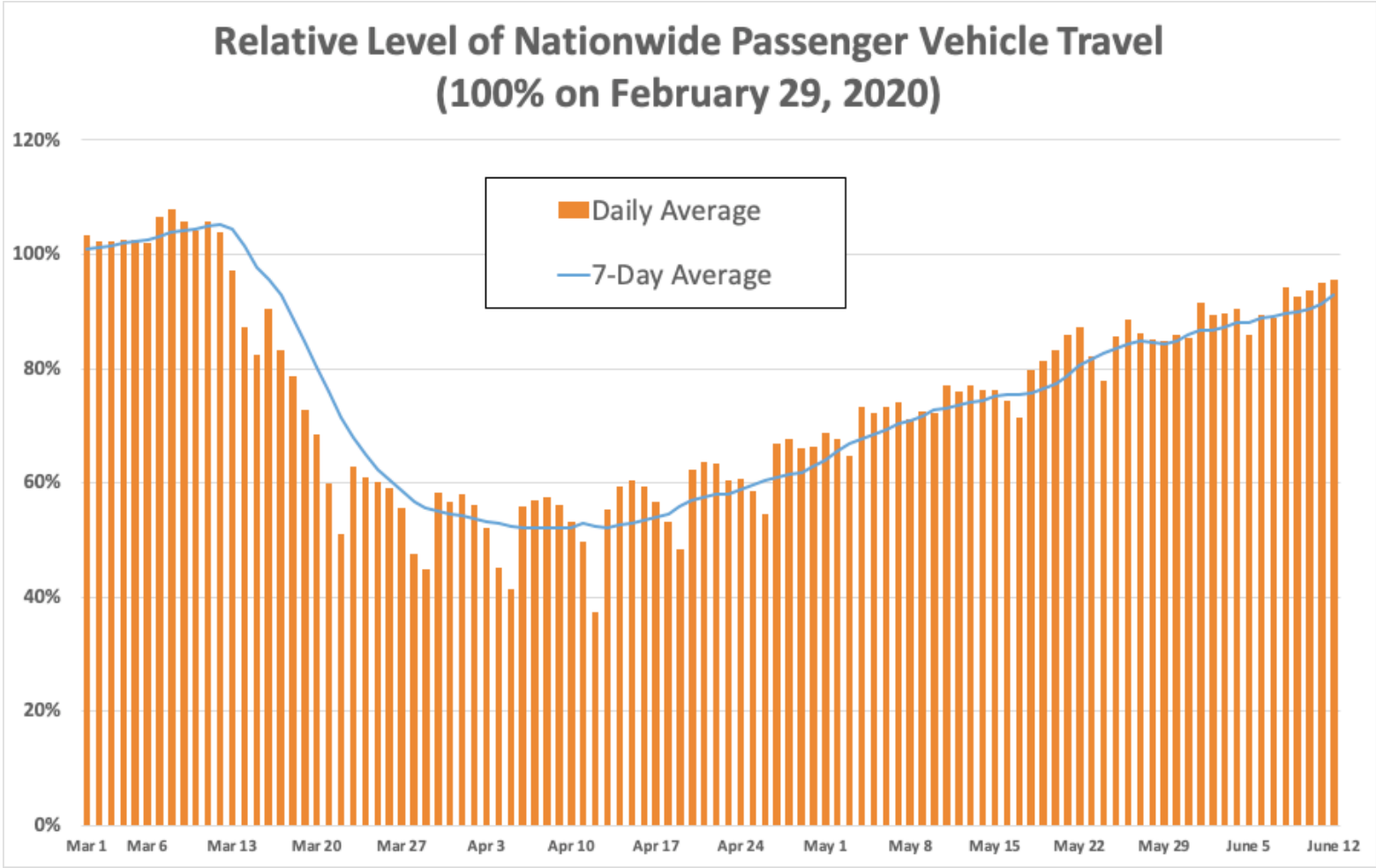
Source: IQ Air

But ..

It is not clear if COVID-19 related shutdown led to uniform reductions in all air pollutants

- NO_2 levels – marker for combustion clearly went down
- $PM_{2.5}$ levels may not have gone down uniformly across U.S.
  - Varies from -30% in NYC to only -1% in Chicago in April
  - Increase in residential wood combustion, soot from trucking activity around urban areas, backyard BBQ cooking
  - Household electricity consumption increases during daytime when dirty generators are prevalent, etc.
- $PM_{2.5}$ has both acute and chronic health impacts
  - Gains in acute, but not in chronic?
- Ozone levels may have actually gone up due to low NO_2 levels
  - Due to reduced non-linear titration effect of NO_2 on Ozone
  - Barcelona, Spain saw 50% increase in Ozone, while NO_2 went down by 50% *(Tobias et al, 2020)*

Personal Travel Dropped a Lot..



Source: INRIX

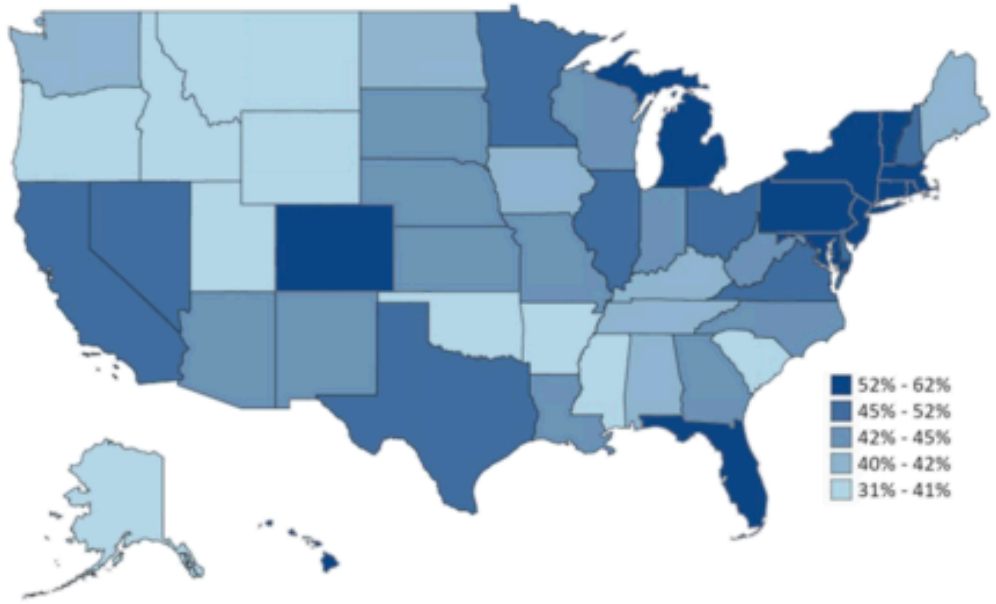
While we saw > 50 – 60% drop in early April, personal travel has increased quite a bit from peak reduction for all 98% metro areas in the U.S.

But Freight, not as much

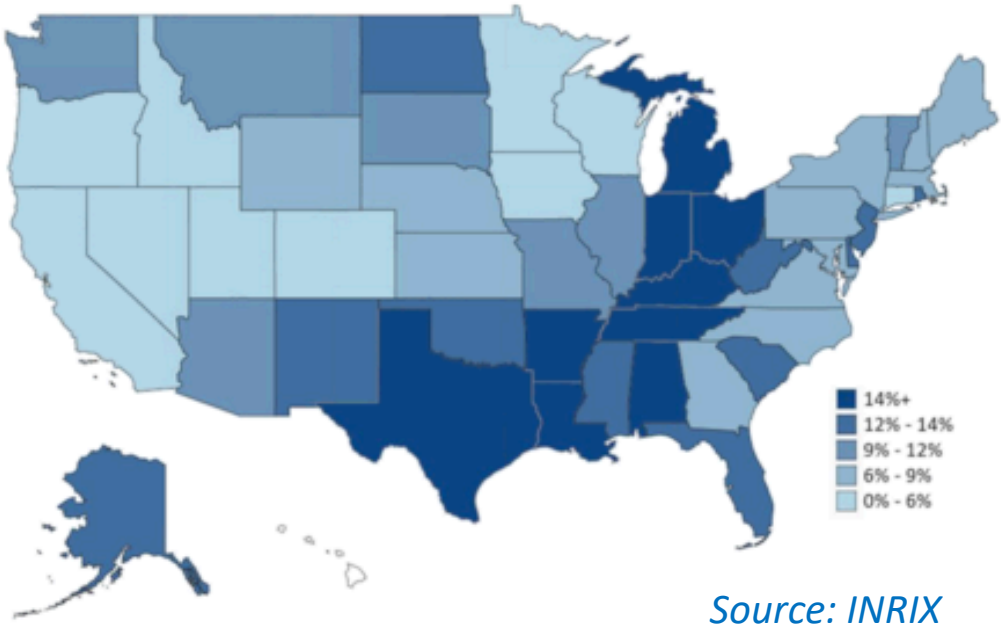
Findings

Passenger and Freight Travel Decreased during COVID-19

Passenger Travel Down 46 Percent Nationwide



Freight Travel Down 13 Percent Nationwide



Source: INRIX

- While passenger travel went down, freight travel didn't see too much decrease nation-wide
  - *In fact, had increases in several urban areas*

Objectives

- Quantify incremental benefits in health due to reduced levels of O_3, NO_2 and $PM_{2.5}$ due to reductions in
  - Onroad transportation
    - By light duty (passenger cars) vs. heavy duty (trucks)
    - In the entire U.S. and by each individual state
  - Commercial aviation
    - In the entire U.S. air space and by each of select top airports

Approach (1 of 2)

CMAQ	Photochemical air quality model that estimates the pollutant concentrations across spatial and temporal **domain** • **Version 5.2**
DDM	Sensitivity analysis that calculates incremental change in pollutant concentrations with respect to model input (**emissions**) across the domain to estimate how sensitive pollutant concentrations are to emissions

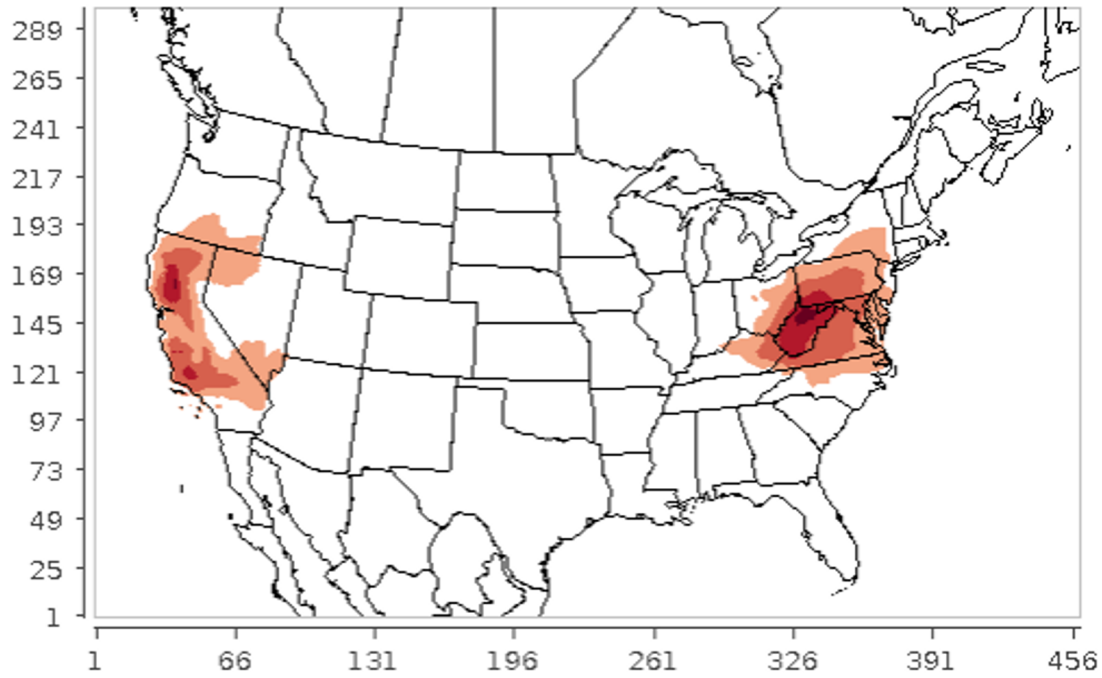
Emissions

Source Regions	By Individual U.S. State for Onroad By Select Airports for Air
Vehicles	Passenger Cars vs. Trucks Commercial Air Traffic
$PM_{2.5}$	NO_X, VOC, SO_2, NH_3, PPM for Onroad NO_X, VOC, SO_2, PPM for Air
O_3	NO_X, VOC

Domain

Spatial
12 x 12 km grids across the Eastern half of the U.S.

Temporal
Model is run for January and July 2016



DDM: Decoupled Direct Method
PPM: Primary Particulate Matter

Approach (2 of 2)

Translate Reductions in Transportation Activity to Health Benefits

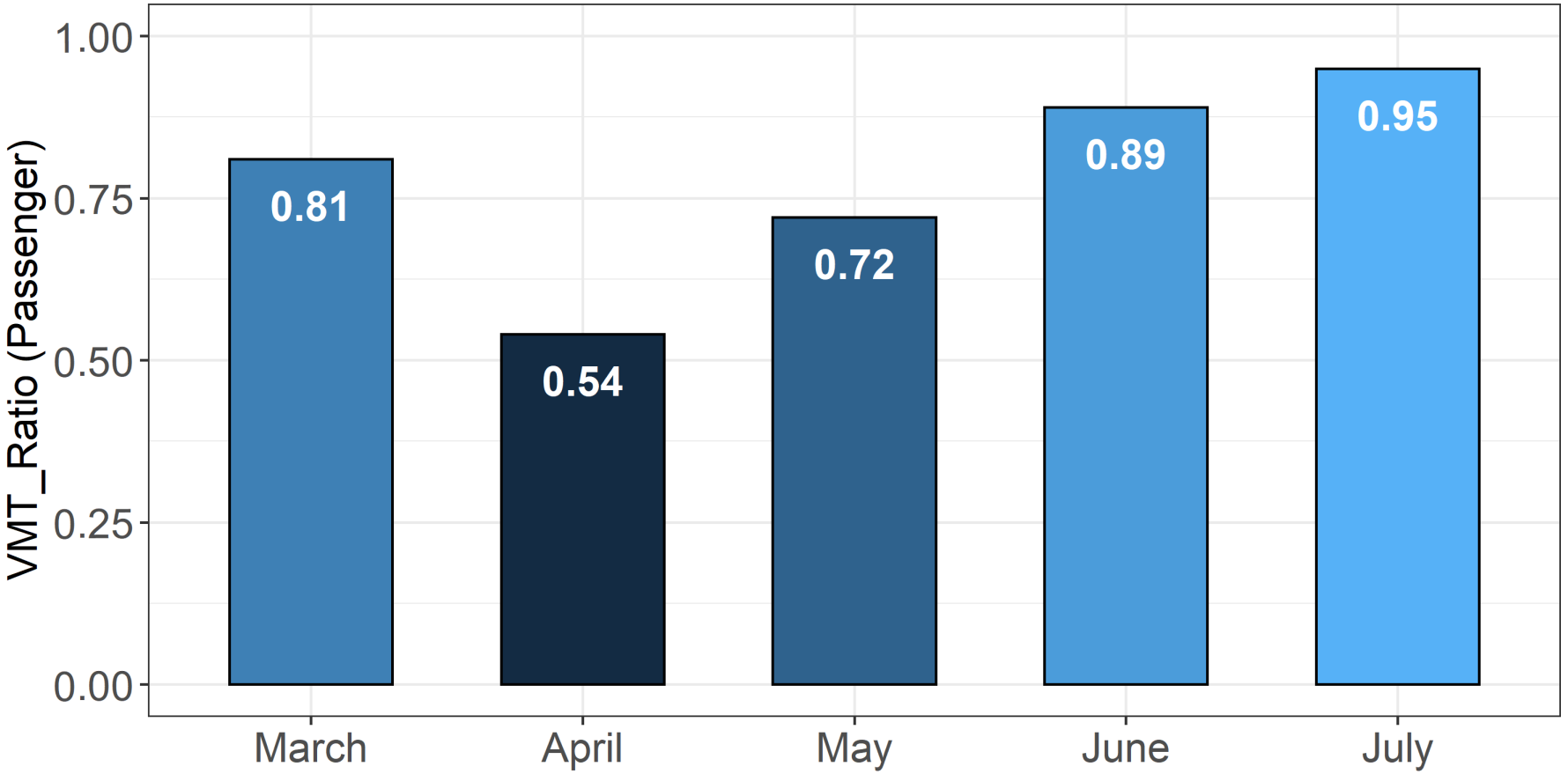
- Parse activity data from Onroad vehicles and Commercial flight operations to compute month-wise ratios (% reduction compared to a baseline)
  - May, June, July 2020 vs. February 2020 for Onroad Sector
  - May, June, July 2020 vs. May, June, Jul 2015 for Commercial Aircraft
- Apply these to CMAQ-DDM based sensitivities for O_3, NO_2 and $PM_{2.5}$
- Perform heath impact calculations and monetize them

Health Impact and Valuation Functions

- $PM_{2.5}$ all-cause mortality Concentration-Response Function (CRF) from Vodonos et al. 2018, 1.29% (1.09 – 1.5%)
- O_3 all-cause mortality CRF from Turner et al. 2016, 0.2% (0.1 – 0.4%)
- NO_2 all-cause mortality CRF from Faustini et al. 2014, 0.21% (0.11 – 0.32%)
- Mortality data from the Centers for Disease Control (CDC) Wide-ranging Online Data for Epidemiological Research (WONDER)
  - https://wonder.cdc.gov/mortSQL.html, county level baseline mortality rates from 1999 to 2016
- Population data from U.S. Census American Community Survey for the year 2018, U.S. Census tract level
- 2016 USD ($) income-adjusted VSL of $10.2M

U.S.-wide reductions

- Onroad Passenger Traffic Activity (VMT)



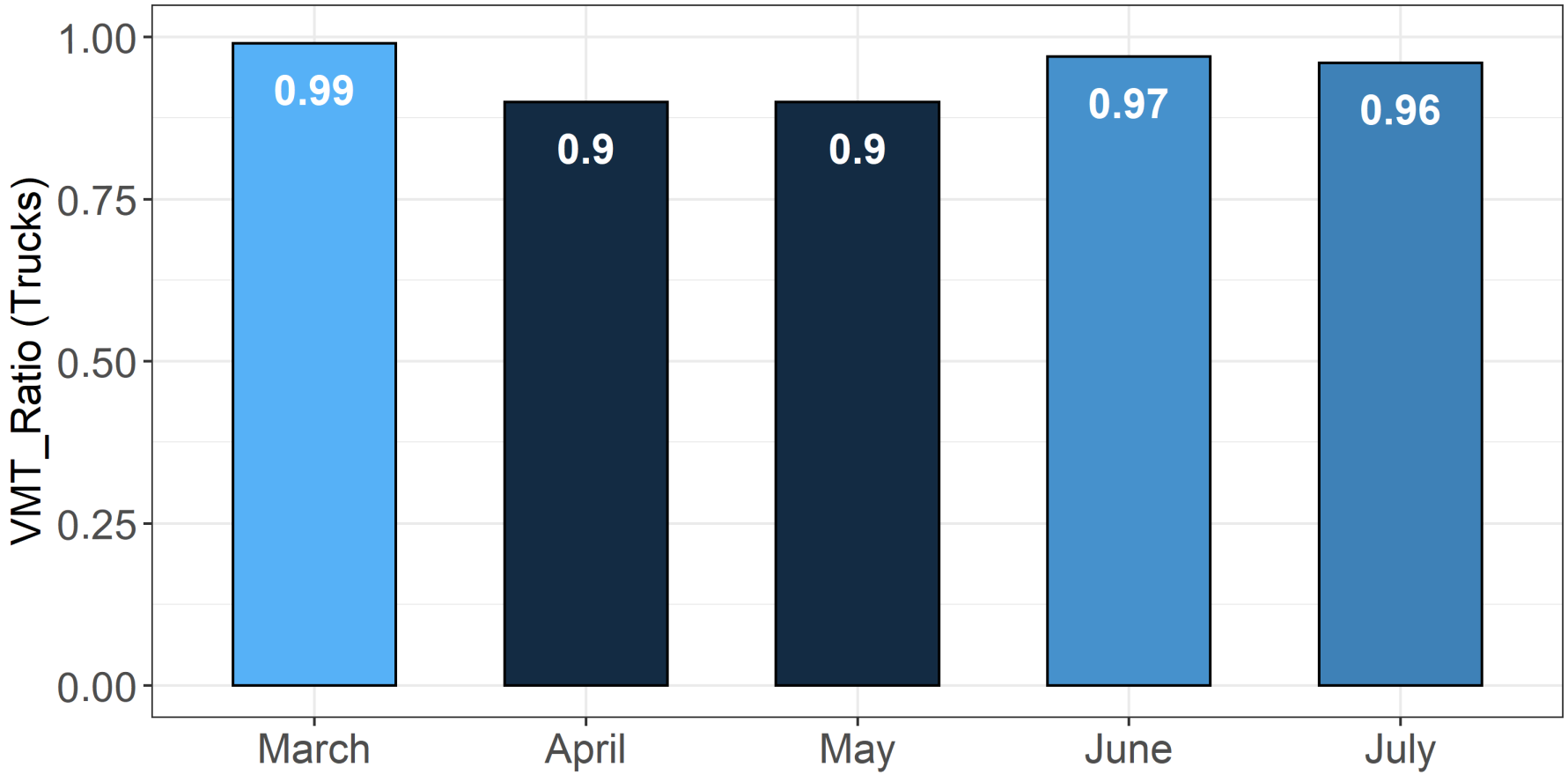
Comparing 2020 by month vs. Feb 2020: April saw the largest reduction

State-specific reductions
- Onroad Passenger Activity (VMT)

- May saw the largest reduction in all States, by up to 62%

Nation-wide reductions

- Onroad Truck Traffic Activity (VMT)



- Comparing 2020 by month vs. Feb 2020: Freight activity reduced only modestly

State-specific reductions
- Onroad Truck Activity (VMT)

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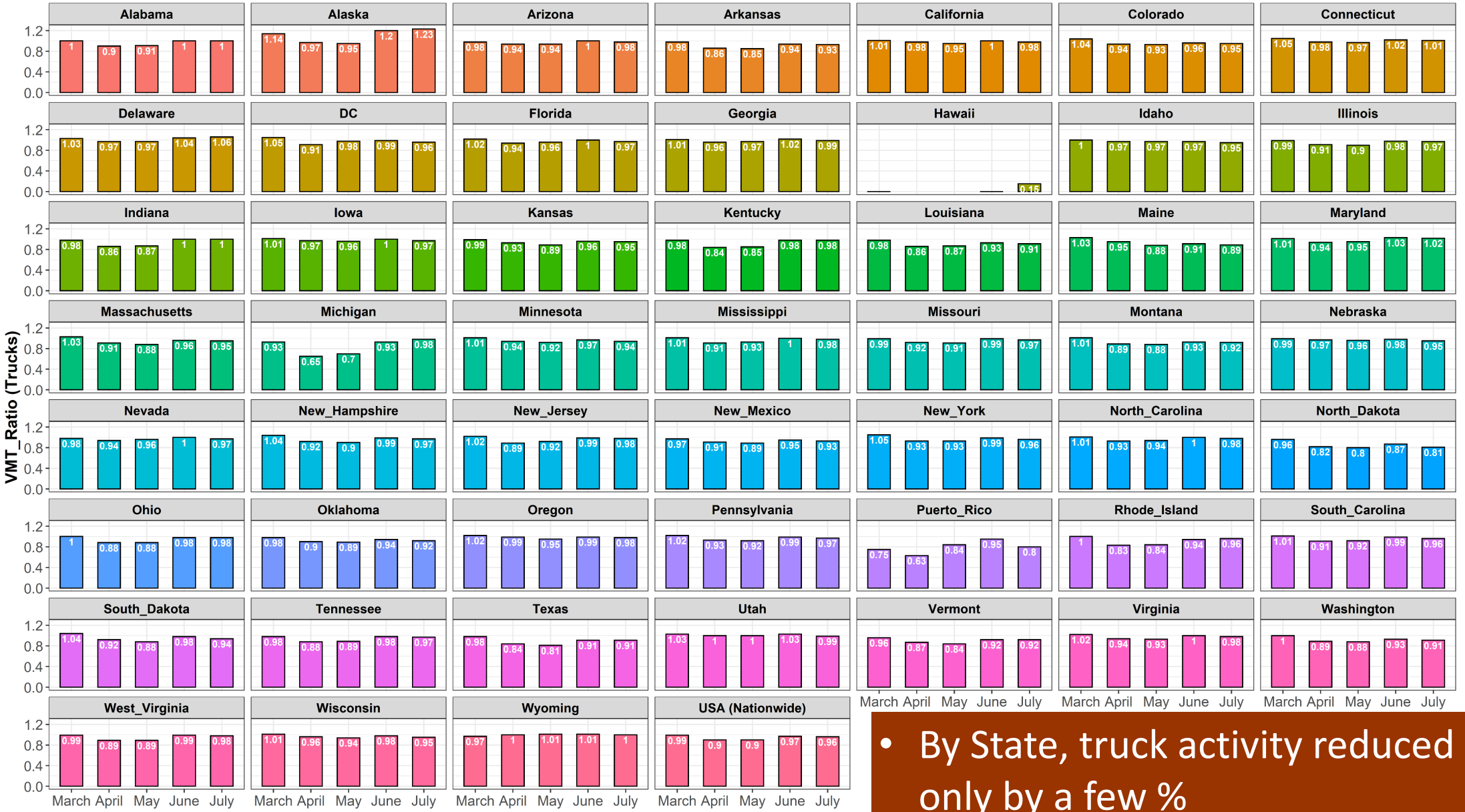
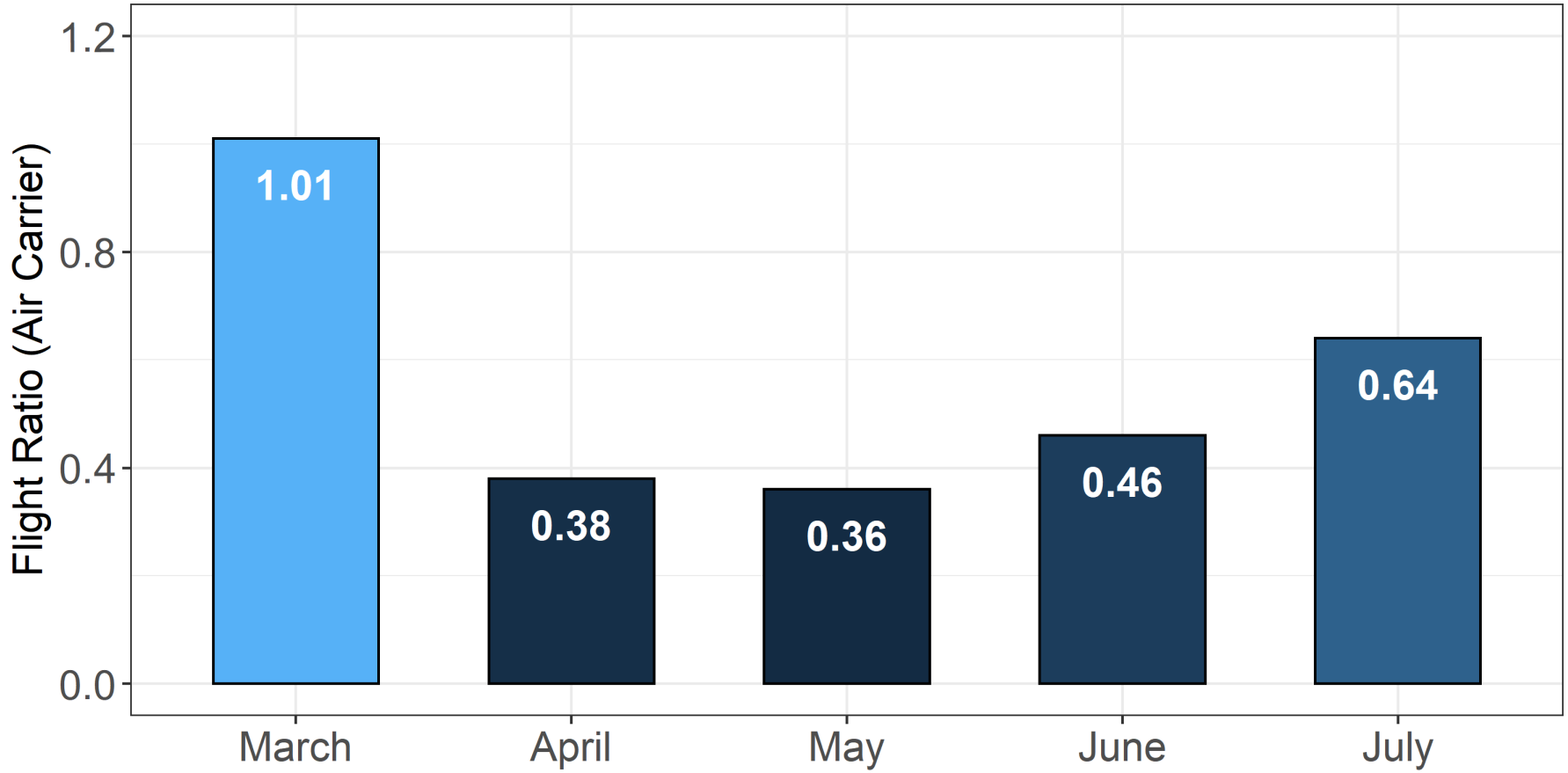


- By State, truck activity reduced only by a few %

U.S.-wide reductions

- Air Traffic Activity (LTO Operations)

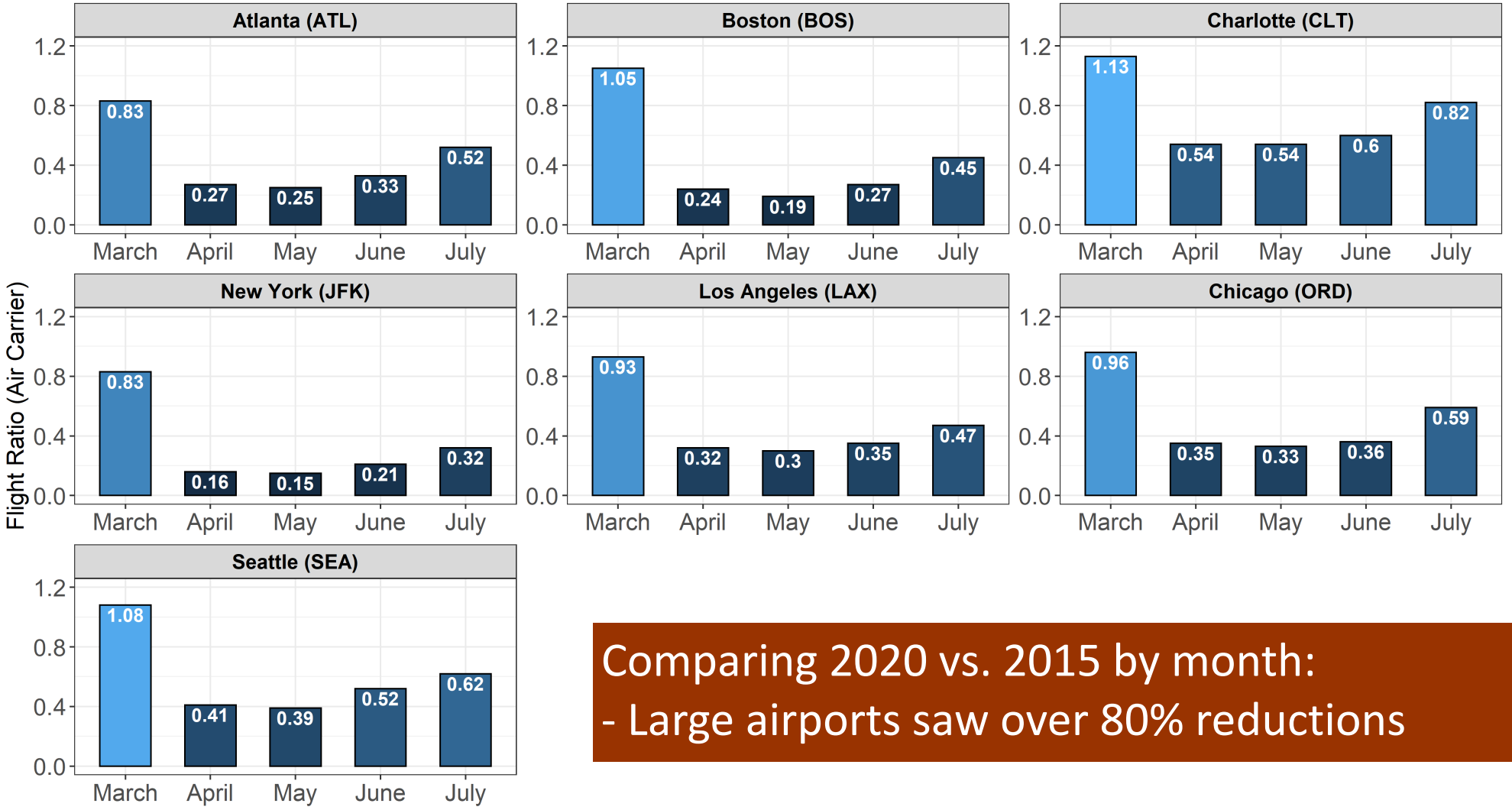


Source: FAA

Comparing 2020 vs. 2015 by month: May saw the largest reduction

Airport-specific reductions

- Air Traffic Activity (LTO Operations)



Comparing 2020 vs. 2015 by month:
- Large airports saw over 80% reductions

Change in $PM_{2.5}$ concentrations due to reduction in Passenger vehicle activity in Arkansas

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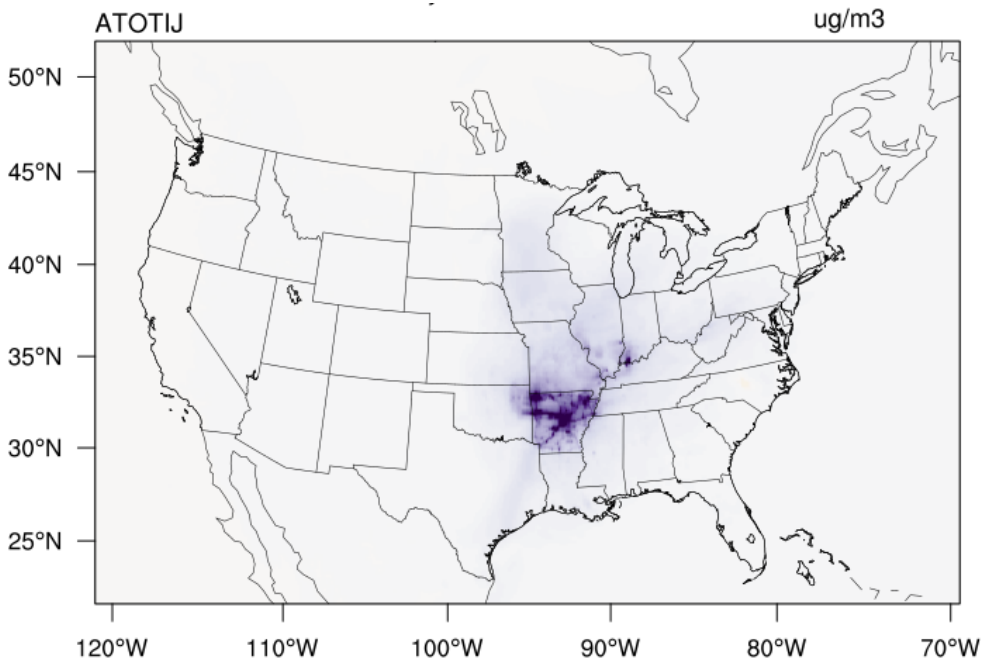
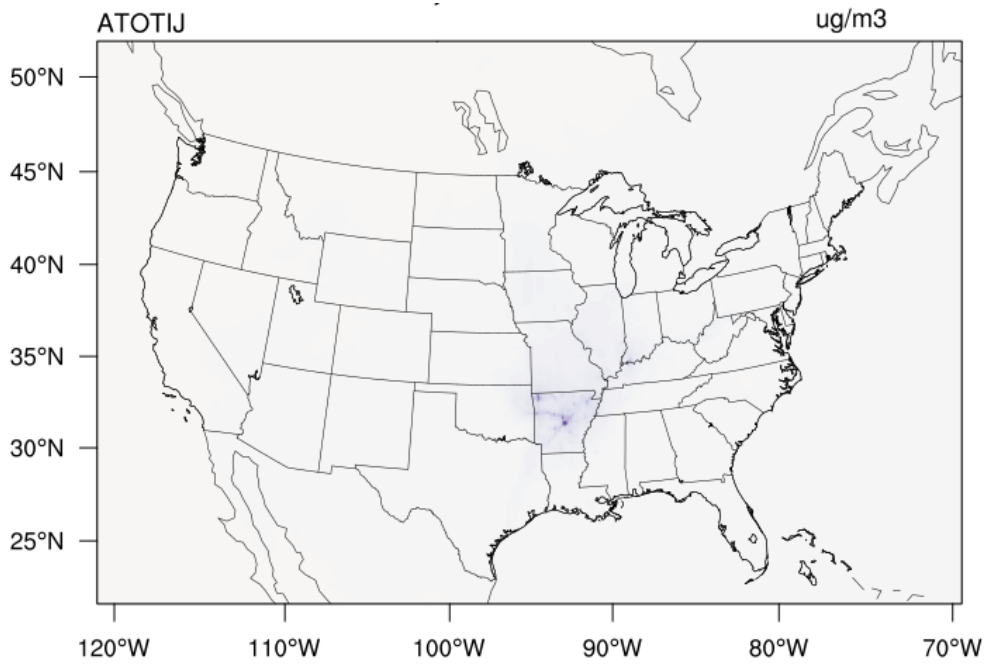
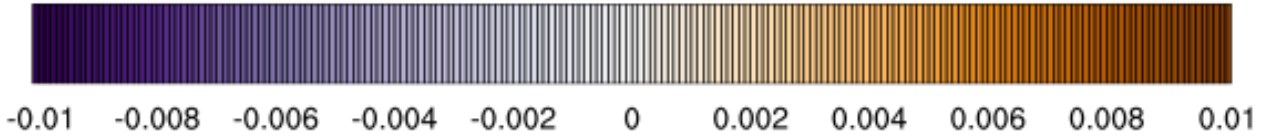
-20% in May



-4% in June





$\mu g/m^3$

*July had 0% change in VMT

CONUS grids	% Decrease in VMT	Average	Median	Max	Min
May_ratio	20%	-0.00046	-8.85e-05	0.00037	-0.037
Jun_ratio	4%	-9.23e-05	-1.76e-05	7.49e-05	-0.008

Change in O_3 concentrations due to percent change in Passenger vehicle activity in Arkansas

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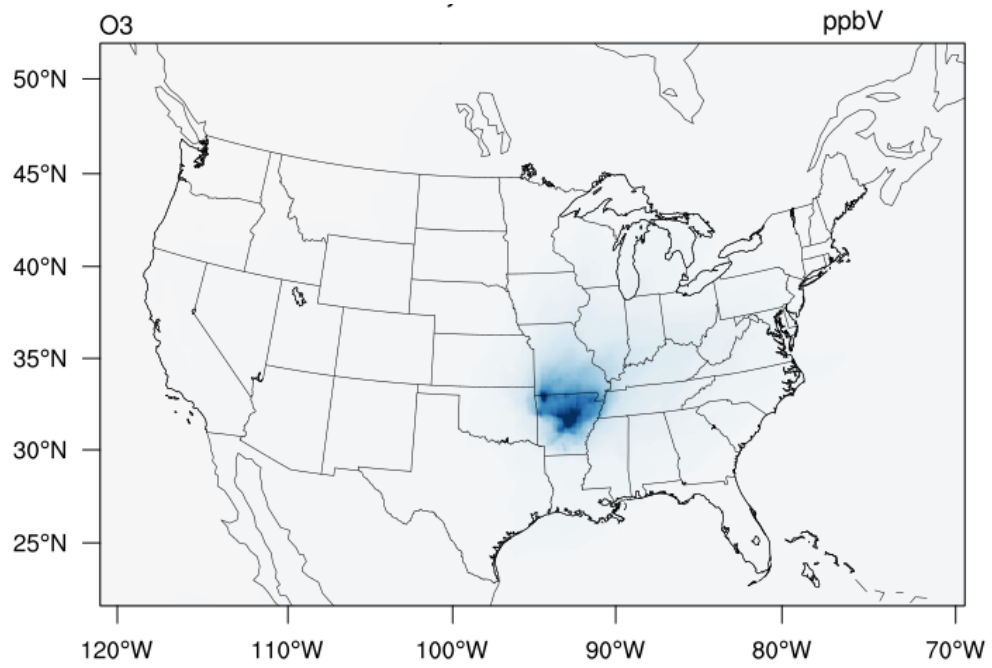
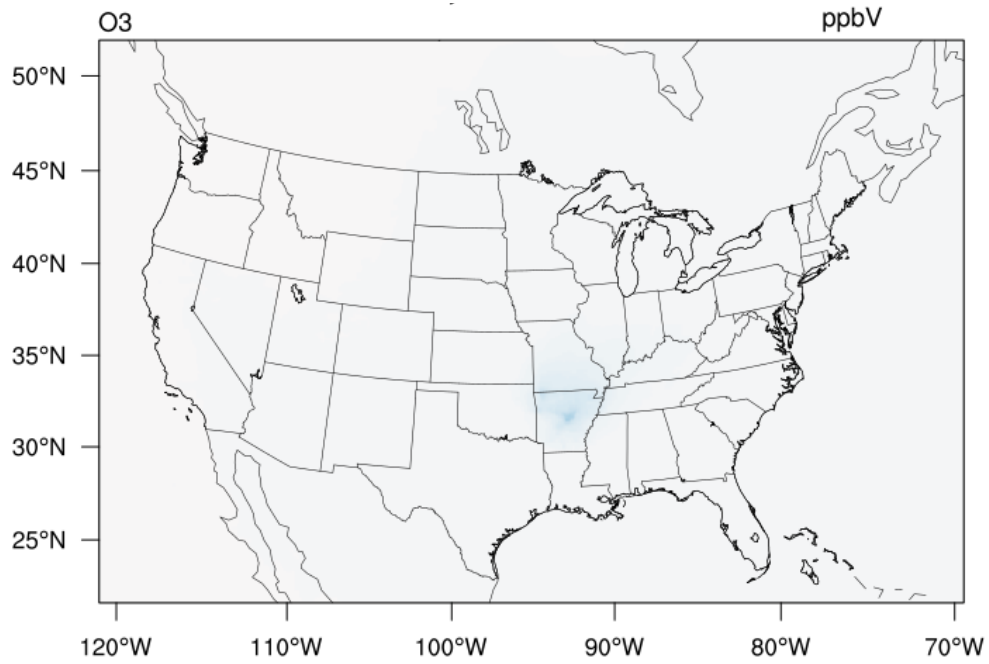
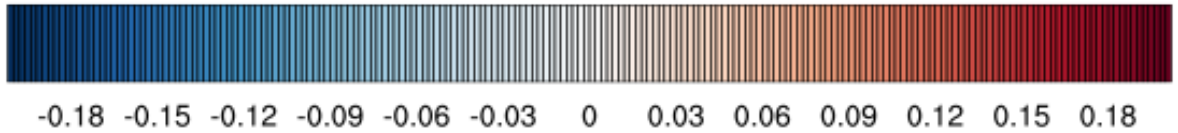
-20% VMT in May



-4% VMT in June





ppbV

*July had 0% change in VMT

CONUS grids	% Decrease in VMT	Average	Median	Max	Min
May_ratio	20%	-0.0072	-0.0014	0	-0.33
Jun_ratio	4%	-0.0014	-0.0002	0	-0.07

Change in NO_2 concentrations due to reduction in Passenger vehicle activity in Arkansas

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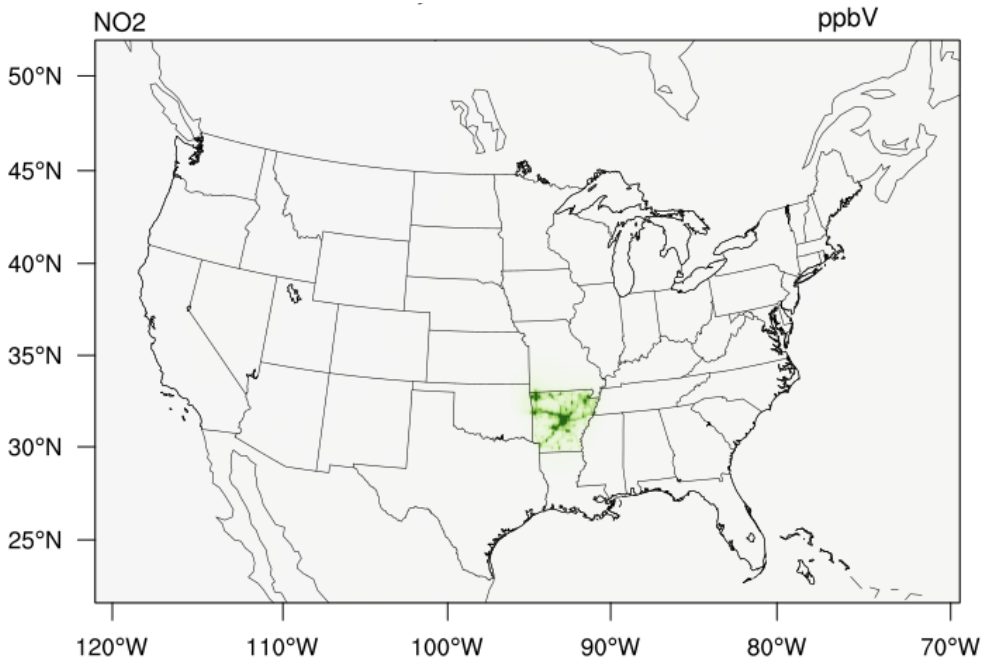
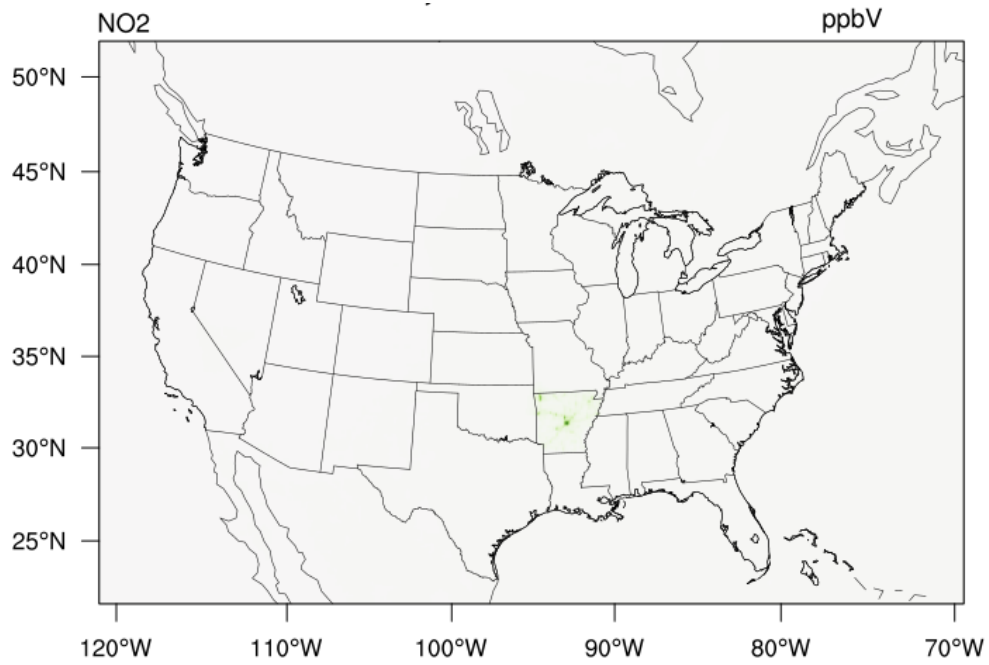
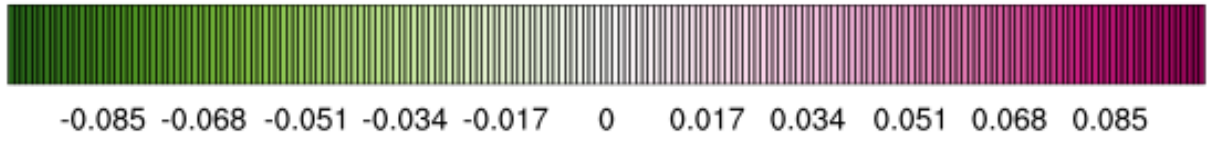
-20% VMT in May



-4% VMT in June





*July ratio was 0% change in VMT

CONUS grids	% Decrease in VMT	Average	Median	Max	Min
May_ratio	20%	-0.00087	-8.46e-06	0.00036	-0.41
Jun_ratio	4%	-0.00017	-1.67e-06	7.15e-05	-0.08

Reduction in Premature mortalities due to percent change in Passenger vehicle activity in Arkansas

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	May Ratio -20% VMT Activity		June Ratio -4% VMT Activity	
	Premature Mortalities (95% CI)	Valuation (2016 USD)	Premature Mortalities (95% CI)	Valuation (2016 USD)
$PM_{2.5}$	22.3 (18.8 - 25.9)	$230M ($190M - $260M)	4.46 (3.76 - 5.18)	$45M ($38M - $53M)
O_3	46.5 (23.2 - 92.9)	$470M ($240M - $950M)	9.29 (4.65 - 18.6)	$95M ($47M - $190M)
NO_2	8.14 (4.07 - 12.2)	$80M ($40M - $120M)	1.63 (0.814 - 2.44)	$17M ($8M - $25M)
Total	77	$780M	15	$160M

*July ratio was 0% change in VMT

Reduction in Premature mortalities due to percent change in Freight vehicle activity in Arkansas

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	May Ratio -15% VMT Activity		June Ratio -6% VMT Activity		July Ratio -7% VMT Activity	
	Premature Mortalities (95% CI)	Valuation (2016 USD)	Premature Mortalities (95% CI)	Valuation (2016 USD)	Premature Mortalities (95% CI)	Valuation (2016 USD)
$PM_{2.5}$	12.8 (10.8 - 14.8)	$130M ($110M - $150M)	5.1 (4.31 - 5.93)	$52M ($44M - $60M)	5.95 (5.03 - 6.92)	$61M ($51M - $71M)
O_3	22.8 (11.4 - 45.6)	$230M ($120M - $460M)	9.11 (4.56 - 18.2)	$93M ($46M - $190M)	10.6 (5.31 - 21.3)	$110M ($54M - $220M)
NO_2	5.62 (2.81 - 8.43)	$57M ($29M - $86M)	2.25 (1.12 - 3.37)	$23M ($12M - $34M)	2.62 (1.31 - 3.93)	$27M ($13M - $40M)
Total	41	$420M	16	$170M	19	$200M

Reduction in Premature mortalities due to percent change in LTO activity Nation-wide

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	May Ratio -64% Flight Activity		June Ratio -54% Flight Activity		July Ratio -36% Flight Activity	
	Premature Mortalities (95% CI)	Valuation (2016 USD)	Premature Mortalities (95% CI)	Valuation (2016 USD)	Premature Mortalities (95% CI)	Valuation (2016 USD)
$PM_{2.5}$	164 (139 - 191)	$1.67B ($1.41B - $1.94B)	138 (117 - 161)	$1.41B ($1.19B - $1.64B)	92.2 (77.9 - 107)	$0.94B ($0.79B - $1.09B)
O_3	202 (101 - 404)	$2.06B ($1.03B - $4.12B)	170 (85.2 - 341)	$1.74B ($8.69B - $3.47B)	114 (56.8 - 227)	$1.16B ($0.58B - $2.32B)
NO_2	279 (140 - 419)	$2.84B ($1.42B - $4.26B)	235 (118 - 353)	$2.4B ($1.2B - $3.6B)	157 (78.5 - 235)	$1.6B ($0.8B - $2.4B)
Total	645	$6.6B	543	$5.5B	363	$3.7B

Discussion

- COVID-19 related shutdown reduced activity in transportation sector in the first few months
- Used CMAQ-DDM based sensitivities to assess potential benefits in health risk due to changes in O_3, $PM_{2.5}$ and NO_2 from reduced activity in each of commercial aircraft, passenger cars and trucks
- Illustrative results shown for nation-wide for commercial aviation and for Arkansas for onroad activity
  - Upto 645, 77 and 41 premature deaths avoided due to magnitude of reductions in May in aviation (U.S. wide), passenger cars (AR) and trucks (AR) activity respectively
- Ongoing work to complete this analysis for all states and major airports to assess range of benefits due to reduced activity in the transportation sector, and compare/contrast between them

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