August Air Quality Health Monitoring Task Force Meeting

North Central Texas Council of Governments

August 21, 2020

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North Central Texas
Council of Governments

Air Quality Monitoring Strategies and Modeling of Chronic Health Risks Related to Traffic-Related Air Pollution

University of Texas at Arlington

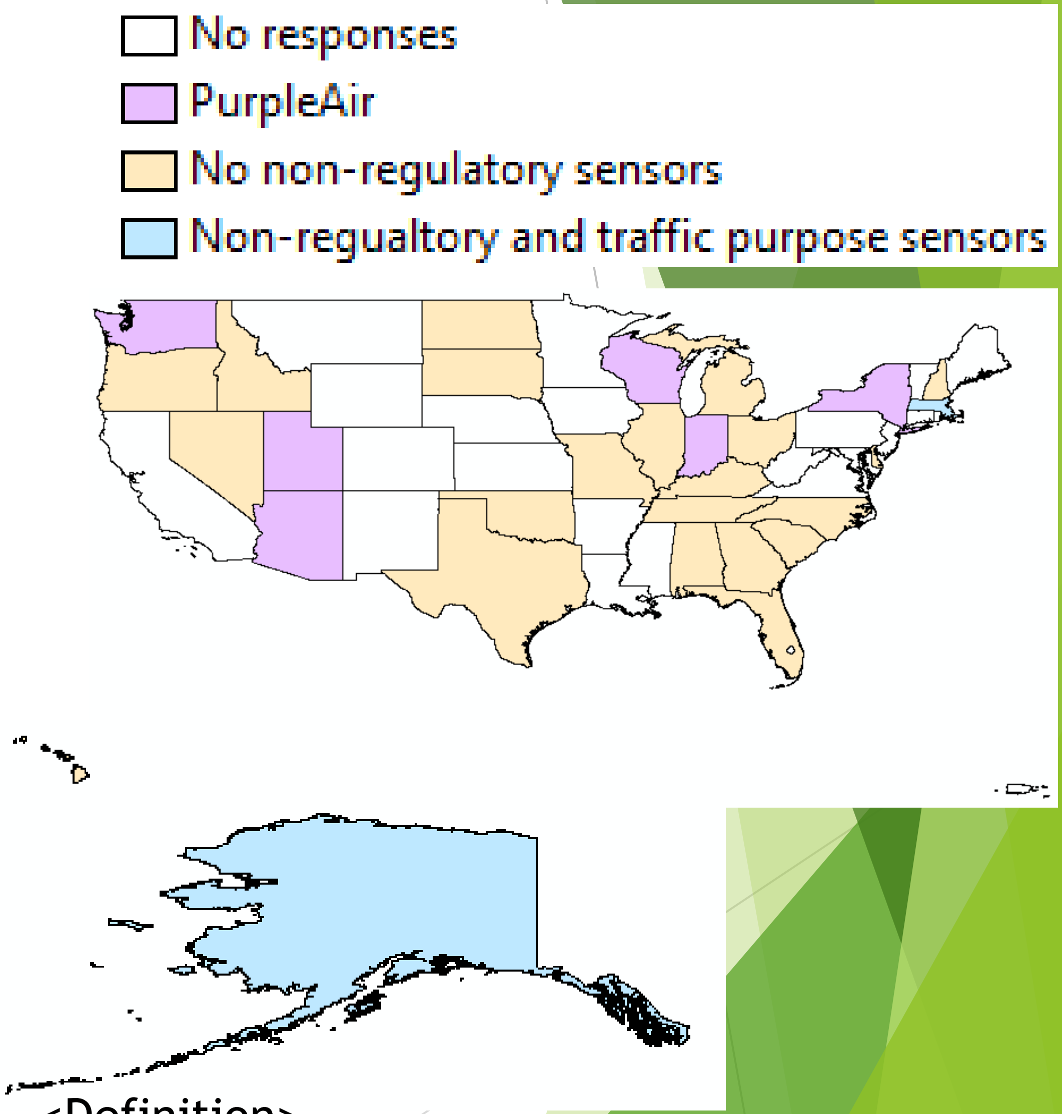
Steve Mattingly and Kate Hyun with Jaesik Choi

Introduction

- An email survey was conducted to 50 State agencies between July – August 2020 (29 agencies responded)
  - The survey collected information on:
    - Type of non-regulatory (low-cost) sensors
    - Operation/maintenance costs and challenges
- Literature review to investigate EPA low-cost sensors
- Comparative analysis to make recommendations for NCTCOG

State Agency Survey

State	Agency	Sensor	Pollutants
AK	Department of Environmental Conservation	Aeroqual AQM-60	PM, CO, SO_2
AZ	Department of Environmental Quality	MetOne E-Bam PurpleAir Thermo-Fisher Scientific ADR-1500	$PM_{2.5}$
IN	Department of Environmental Management	PurpleAir	PM
MA	Department of Environmental Protection	Aethelometers	Black Carbon
NH	Department of Environmental Service	Interagency Monitoring of Protected Visual Environments (IMPROVE) sampler	Ozone, $PM_{2.5}$
NY	Department of Environmental Conservation	PurpleAir	$PM_{2.5}$
UT	Department of Environmental Quality	Dekati cavity ring down particle analyzer PurpleAir (Utah State University)	PM
WA	Department of Ecology	MetOne E-sampler, Alphasense;Clarity, Sensirion; PurpleAir	$PM_{2.5}$
WI	Department of Natural Resources	Dylos, PurpleAir	PM



<Definition>

- Sensors for traffic purpose: sensors installed near the roadside

PurpleAir

- Highlighted from the survey
- Low-cost $PM_{2.5}$ sensors across the US
- Used by 11 agencies (e.g., AZ, IN, NY, UT, WA, WI)
- EPA tried this sensor for capturing PM from wildfire
- EPA evaluated performance of PurpleAir (in 2019).
  - High linearity with FEM monitoring (R-squared value of $PM_{2.5}$ with raw data: 69%)

https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=CEMM&dirEntryId=348236

PM low-cost sensors

AQSPEC (2020), http://www.aqmd.gov/aq-spec/evaluations/summary-pm (accessed on Jun 9, 2020)
https://www2.purpleair.com/collections/air-quality-sensors/products/purpleair-pa-ii (accessed on Jun 9, 2020)
https://www.isweek.com/product/alphasense-pm2-5-particle-sensor-opc-n2_1828.html (accessed on Aug 18, 2020)
EPA (2014), Evaluation of Field-Deployed Low Cost PM Sensors   Alphasense (2019), OPC-N3 Particle Monitor Technical Specification

Vendors and Sensors	PurpleAir PA-II	Alphasense OPC-N3	Dylos DC1100-PRO	Sensirion Nubo	Clarity Node	Sensirion SPS30
Technology	Optical particle counting + laser beams to figure PM type			Laser scattering from advanced	Laser Particle Counter	
Agency	11 states	AQSPEC* EPA	WI AQSPEC EPA	AQSPEC Washington State Department of Ecology		
Data records	Wifi	USB or micro-SD to PC	USB to PC	2G/3G cellular modem to cloud	Wifi or cellular	Connect to PC
Linearity ($PM_{2.5}$)	> 96%	41% to 69%	45%	91%	75%	80%
Maintenance	Not required but visual inspection recommended (removal of spider web)	Minimal maintenance (OPC-N2)	Ease of operation	Low system costs with reliable technology and maintenance (may be required once per year)	Easy to use $600 annual subscription to access data	-Long lifetime (> a decade) -No need for cleaning and maintenance
Capital Cost	$229	$338	$289.99	$2000	$1300	$100

*Air Quality Sensor Performance Evaluation Center

Our recommendation

https://www.sensirion.com/de/umweltsensoren/smart-city/ (accessed on Aug 19, 2020)
http://www.aqmd.gov/aq-spec/evaluations/summary-pm (accessed on Apr 23,2020)

O_3 Sensors (Low-Cost Sensors)

http://www.aqmd.gov/aq-spec/sensordetail/aeroqualS500 (accessed on Aug 16, 2020)

Aeroqual (2011), Aeroqual Ozone Monitors

Wireless Sensor Network	Aeroqual S-500	Aeroqual SM50	uHoo
Detection	Metal Oxide	Gas-sensitive semiconductor	Metal Oxide
Agency	AQSPEC	EPA	AQSPEC
Data logging	USB cable to user interface	No storage or no display No re-calibration	Cloud-based (Wifi supported) Smartphone applications
Pollutants	O_3	O_3	Volatile Organic Compounds $PM_{2.5}$, CO, CO_2 and O_3
Linearity (R^2) of O_3	0.85	0.83 to 0.94	0.43 to 0.72
Error term (%)	7 to 17	Unknown	
Maintenance	Vendor recommends replacing the sensor head every two years	Expected life is a year	- Parts do not need replacement - No maintenance (except cleaning)
Capital Cost	$500	$325	$329

Our recommendation

https://www.aeroqual.com/pre-purchase-faqs/portable-air-quality-monitor (accessed on Aug 20, 2020)

NO_2 Sensors (Low-Cost Sensors)

Wireless Sensor Network	CairPol Cairsens (Cairclip)	Platypus Technologies LLC Prototype	CitiSense CARTOLA
Technology	Electrochemical sensors	thin film liquid crystal (LC) mounted to a metal strip	Electrochemical NO2 sensor
Agency	EPA AQSPEC	EPA	EPA
Data logging	USB	Display, RS-232	Smartphone device over Bluetooth
Pollutants	CO, NH_3, H_2S, mercaptans, SO_2, PM, O_3 and NO_2	NO_2	CO, NO_2, O_3
Linearity of NO_2	0.0 to 0.12	0.8	0.98
Maintenance or operating Cost	No maintenance; Calibration every year	LC film needs to be replaced (the frequency of film replacement is unknown)	Recalibrate every 3-6 months Replace every 12-16 months for accurate results
Capital Cost	$1,198	Unavailable	Unavailable

EPA (2014), Sensor Evaluation Report

Other Feedback from State Agencies

- WI uses Purple Air and monthly visual inspection to remove webs or bugs from the sensors. WI expects the life of PurpleAir sensors as 1.5 years.
- WA tested some of the low-cost sensors, Alphasense, Clarity, Sensirion and PurpleAir, to measure $PM_{2.5}$.
  - WA observed the highest accuracy and correlation from Plantower sensors (PurpleAir and Clarity) and the worst performance from Alphasense units
  - WA plans to deploy low-cost $PM_{2.5}$ sensors for wildfire monitoring
- AK uses AQM-60 for traffic emissions (installed near the road)
  - AK spends maintenance costs of $40,000/year for five sensors
  - Gaseous sensors require filter change every week, and PM sensors twice a year
- MA uses aethelometers for black carbon monitoring near-road, urban (traffic and other sources) and wood smoke.
  - Total cost: $32,000 each
  - Monthly maintenance required: clean an intake screen and check flow (~1 hour)

Conclusion

- Many States use low-cost sensors to measure PM
  - Two agencies use low-cost sensors to capture wildfire pollution (AZ, MA);
  - Three states (AK, MA and NH) collect gaseous pollutants with their own low-cost sensors
- Our recommendation is based on the following factors:
  - Cost (capital & operation)
  - Ease of operation/maintenance
  - Data record/logging –Wifi capability or cellular modem
  - Accuracy
  - Longevity (life span)

- Purple Air for PM ($229; minimum maintenance; Wifi supported)
- uHoo for O_3 ($329; minimum maintenance; Wifi supported); if accuracy is preferred Aeroqual may produce a better sensor
- No clear winner for NO_x

Evaluating Air Quality, Health and Environmental Justice in Houston
Methods and Takeaways for the DFW Region

P. Grace Tee Lewis, PhD

August 21, 2020

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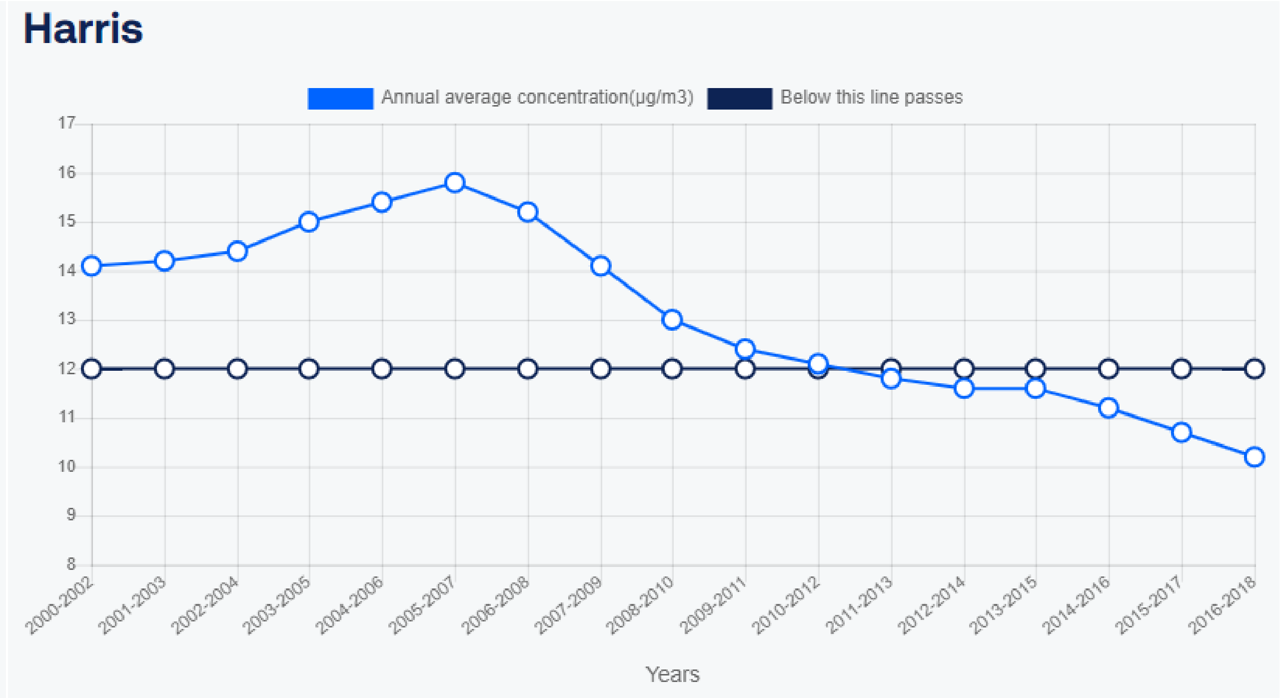
Houston Air Quality 2020

American Lung Association. State Of The Air

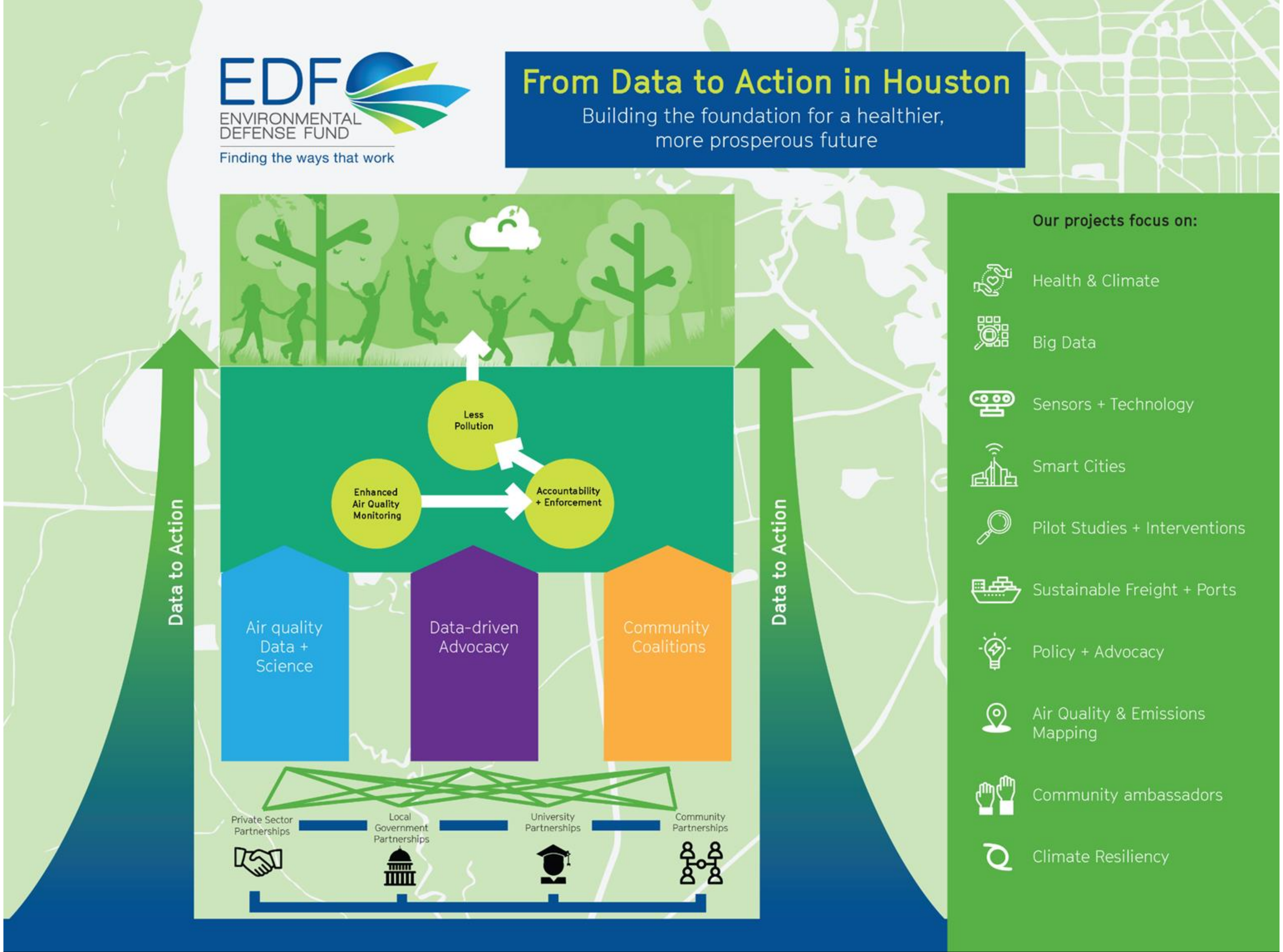
- Ranked 14 for high ozone days out of 229 metropolitan areas
- Ranked 56 for 24-hour particle pollution out of 216 metropolitan areas
- Ranked 22 for annual particle pollution out of 204 metropolitan areas

http://www.stateoftheair.org/city-rankings/msas/houston-the-woodlands-tx.html#pmann

Annual Particle Pollution (μg/m³)



	Houston MSA
Total Population	7,183,143
Pediatric Asthma	150,124
Adult Asthma	395,360
COPD	317,982
Lung Cancer	3,559
Cardiovascular Disease	462,780
Ever Smokers	1,889,106
Children Under 18	1,897,159
Adults 65 & Over	809,495
Poverty Estimate	1,018,964
Non-White	4,591,549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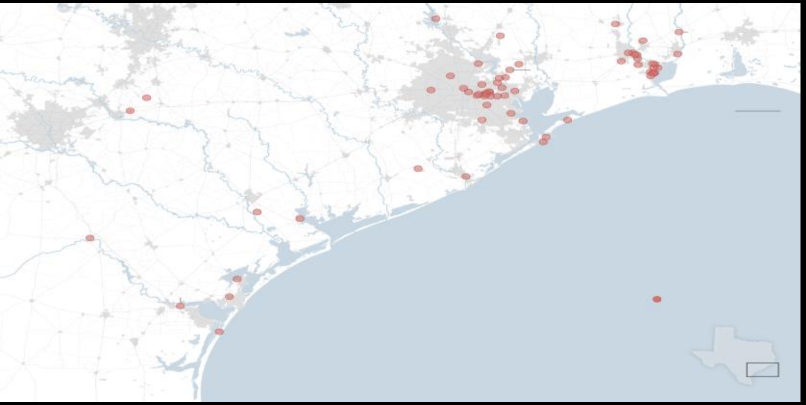
ENVIRONMENTAL DEFENSE FUND
Finding the ways that work
From Data to Action in Houston
Building the foundation for a healthier, more prosperous future
Less Pollution
Enhanced Air Quality Monitoring
Accountability + Enforcement
Data to Action
Data to Action
Air quality Data + Science
Data-driven Advocacy
Community Coalitions
Private Sector Partnerships
Local Government Partnerships
University Partnerships
Community Partnerships
Our projects focus on:
Health & Climate
Big Data
Sensors + Technology
Smart Cities
Pilot Studies + Interventions
Sustainable Freight + Ports
Policy + Advocacy
Air Quality & Emissions Mapping
Community ambassadors
Climate Resiliency




NORTH
Intercontinental Airport
10 WEST
San Antonio
10 EAST
Downtown
EXIT ONLY







Data to Action: Community Action Planning

Identifying Environmentally Vulnerable Houston Communities

Ranking Census Tracks in the HGB area
EPA Toxicological Prioritization Index (ToxPi)

International Journal of
Environmental Research and Public Health

Article

HGBEnviroScreen: Enabling Community Action through Data Integration in the Houston–Galveston–Brazoria Region

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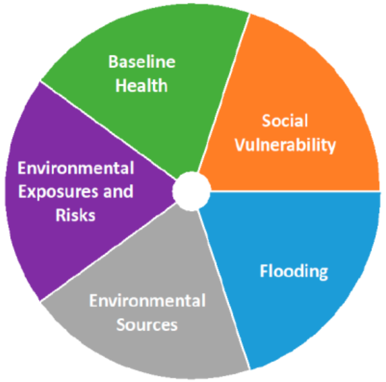
HGB Enviroscreen Methodology



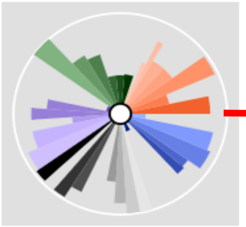
Integrating Data

Multiple Domains

1. Health
2. Social Vulnerability
3. Flooding
4. Environmental Sources
5. Environmental Exposures & Risks

What's Driving Vulnerability?

SocioecoTh	0.8234
HousenDisab	0.4085
MinoritynLang	0.9637
HousenTran	0.5586
Uninsured	0.5623
MRFEI	0.7800
FoodLowAccess	0.5000
Food Insecurity	0.1892
StrokeCPrev	0.3263
CAsthCPrev	0.3146
COPDCPrev	0.3130
CHDCPrev	0.5755
LifeExp	0.6325
Hospital 5kmCt	1.0000
RSEI	0.0397
ACancerRsk	0.6552
RespiroNonC	0.8146
ReprodNonC	0.3915
Avg3yrPM25_Sat	0.8231
Avg3yrPm25	0.9370
Petr_Oil_1kmCt	0.9660
CBPnCem_1km	0.0000
MetalR1kmCt	0.9734
LeakPSTCt	0.8384
PPlnt1kmCt	0.0000
SF_Ct	0.0000
MajRd1kmCt	0.6391
RMP_Count	0.8724
RMP_Accid	0.9881
RMP_Shelt	0.9945
Flood 100yr	0.0902
Flood 500yr	0.0098
FEMA_AFF	0.7778
FEMA_MIN	0.7567
FEMA_MAJ	0.9109
FEMA_DES	0.8751
CANSrDNeed	0.1514



8 County HGB Region, 1090 Census Tracts

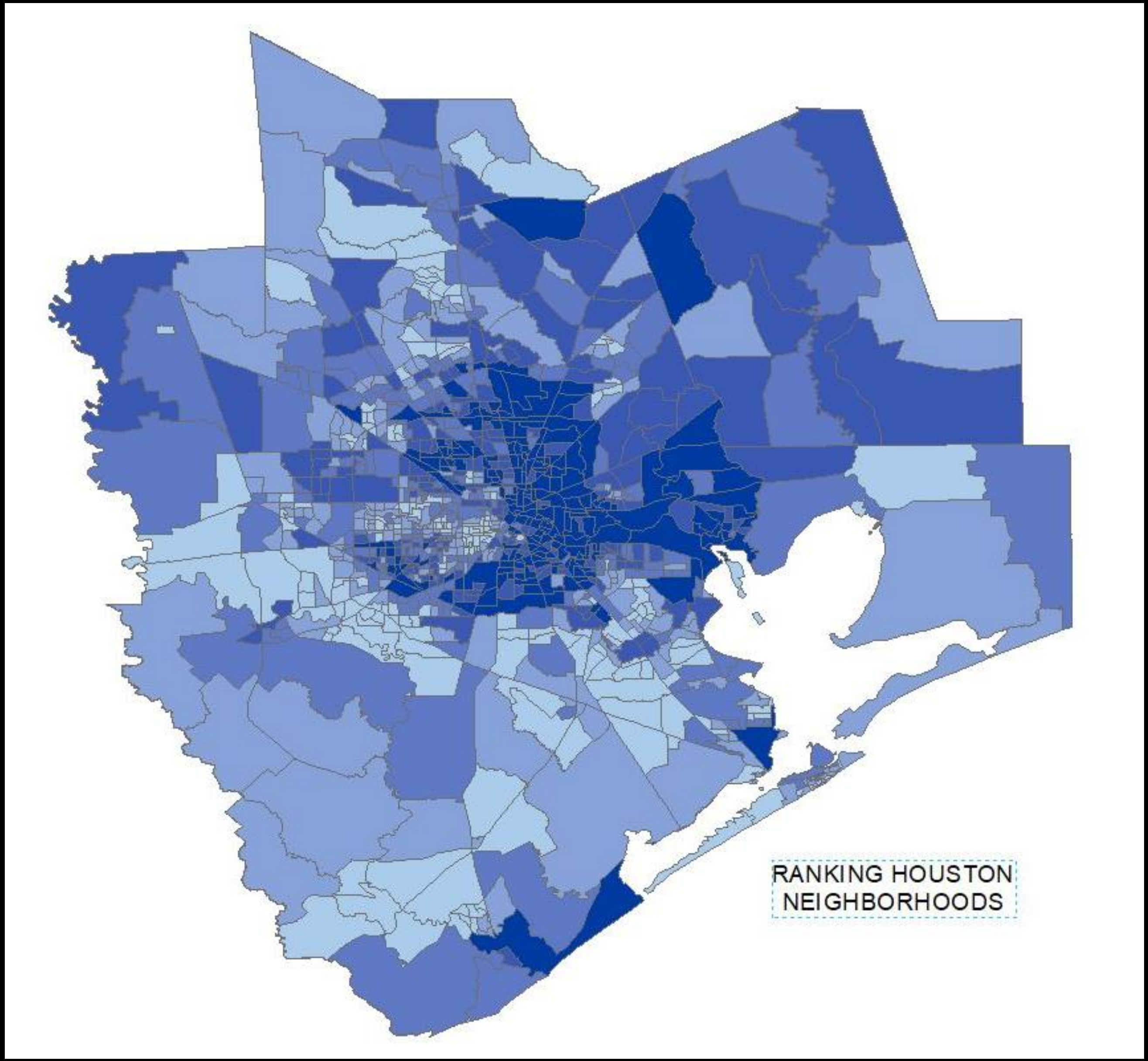
www.hgbenviroscreen.org

Index Score
Census Tract Level Risk Ranking

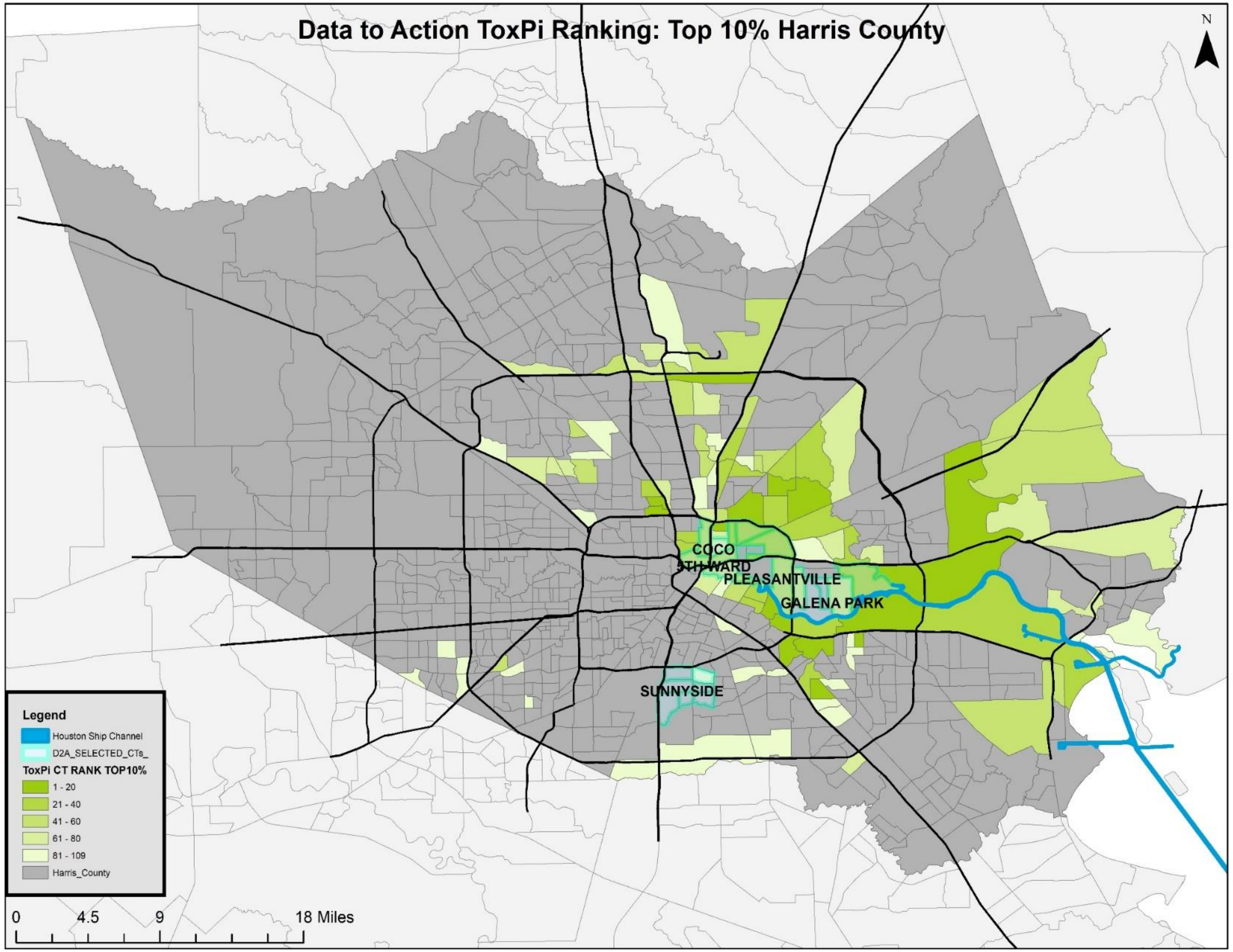
Local Data
Wedges Proportional to Driver Contribution

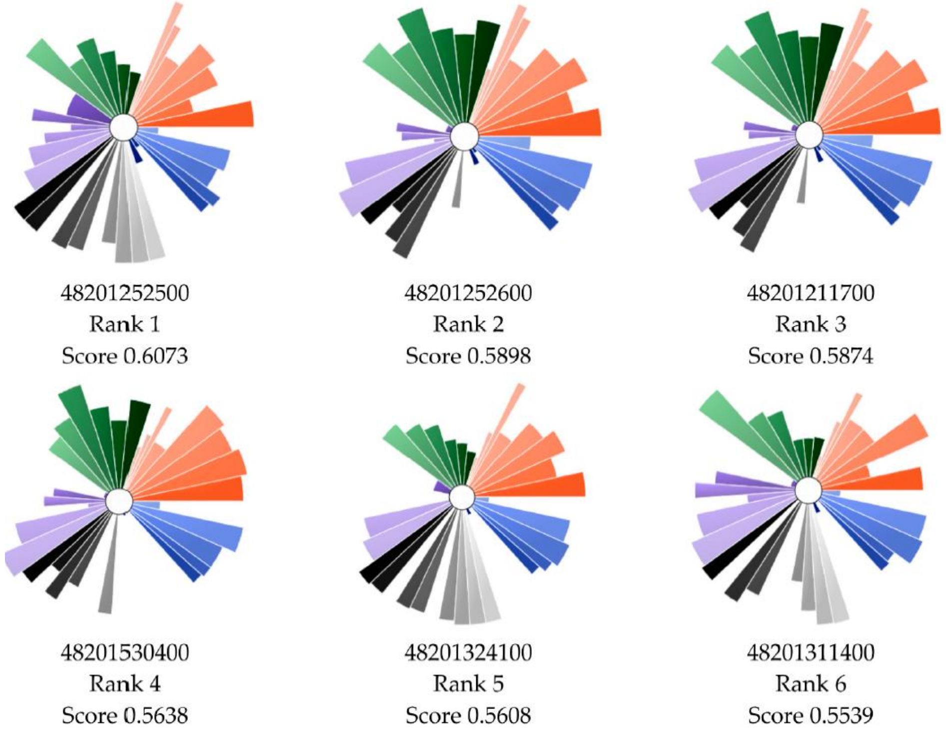
ArcGIS
Integrated Geospatial Visualizations

Ranking Houston Census Tracts (n=1090)

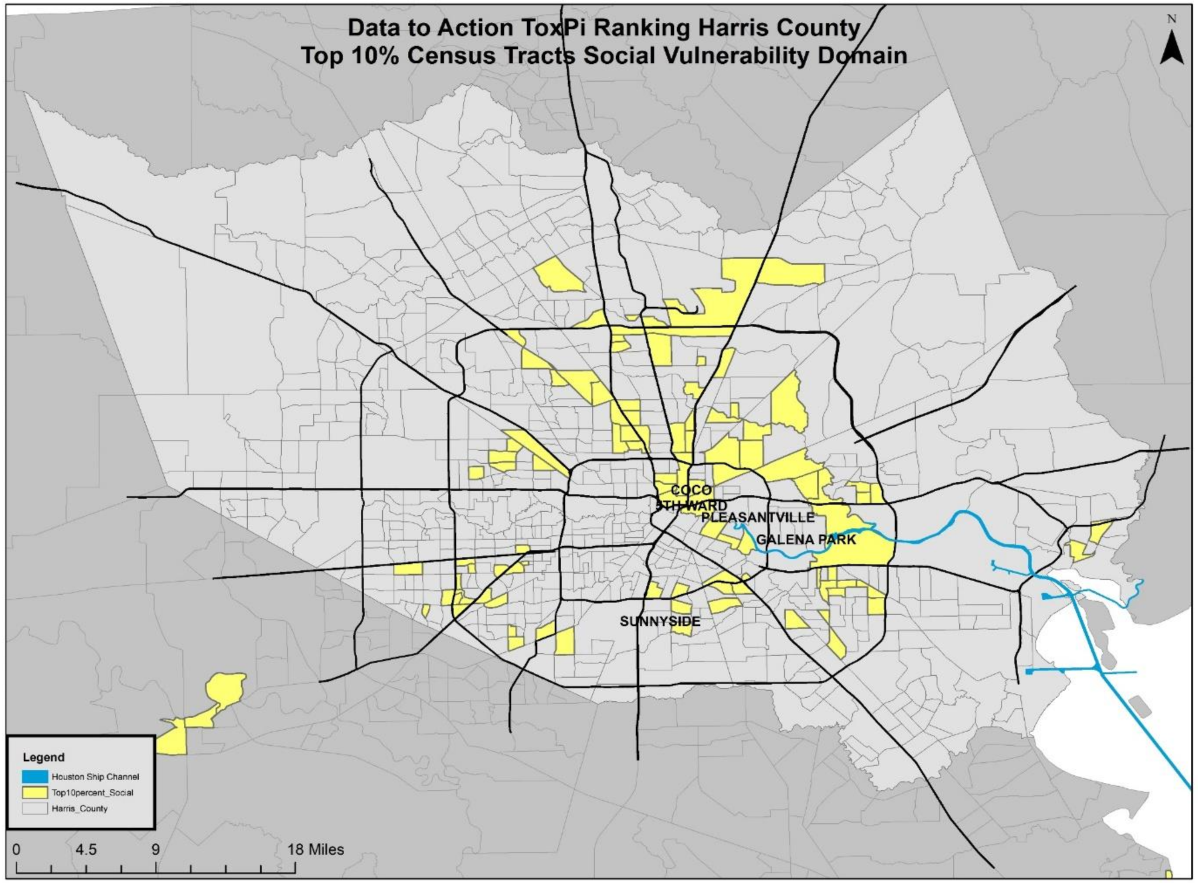


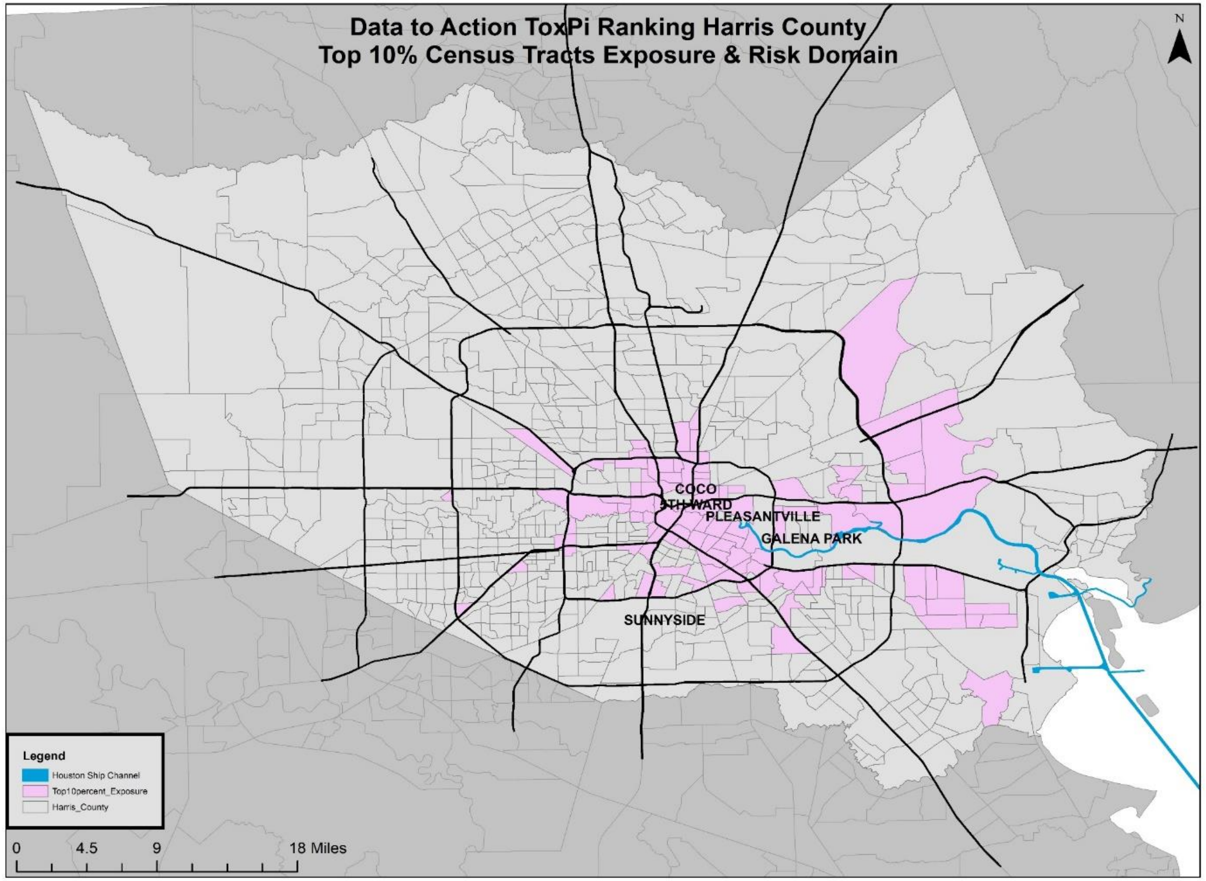
Understanding Drivers of Vulnerability



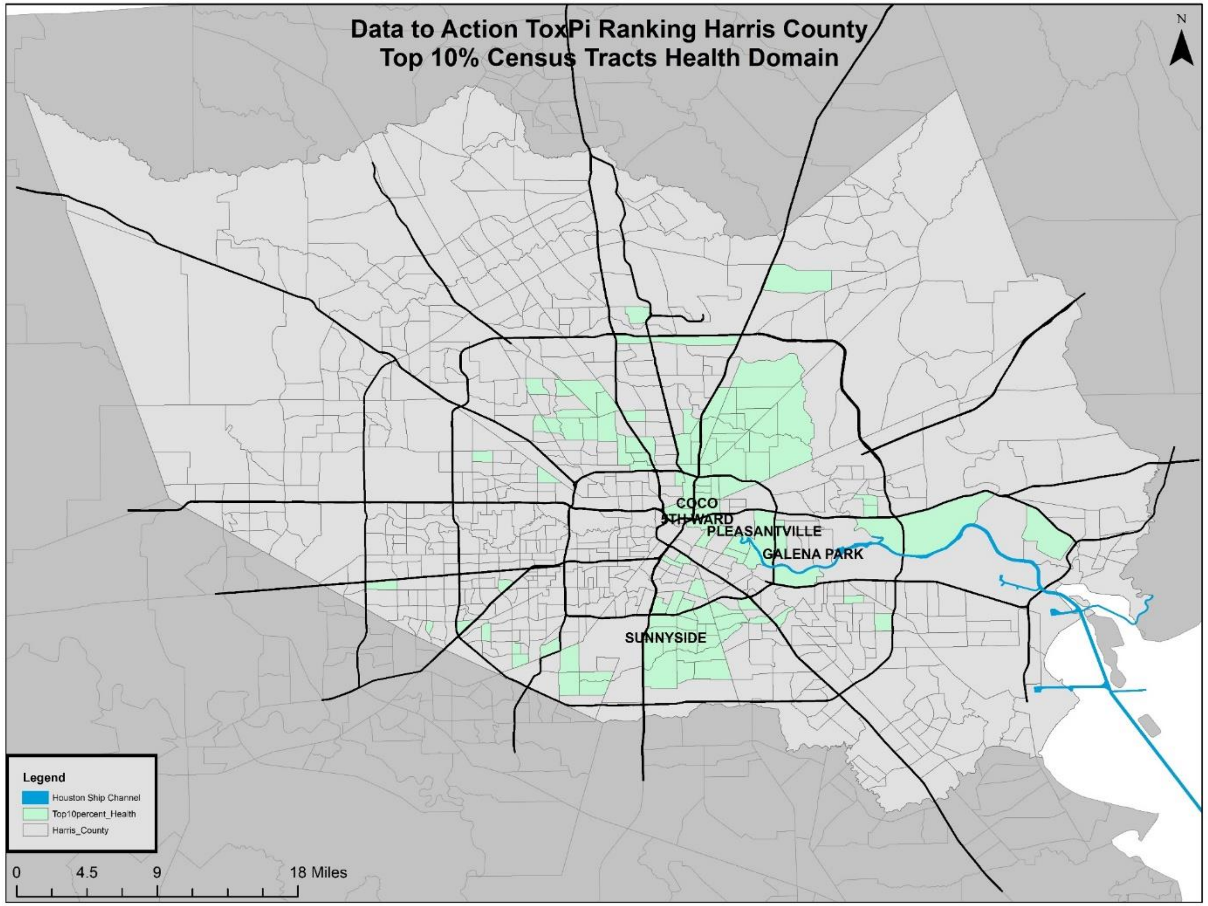


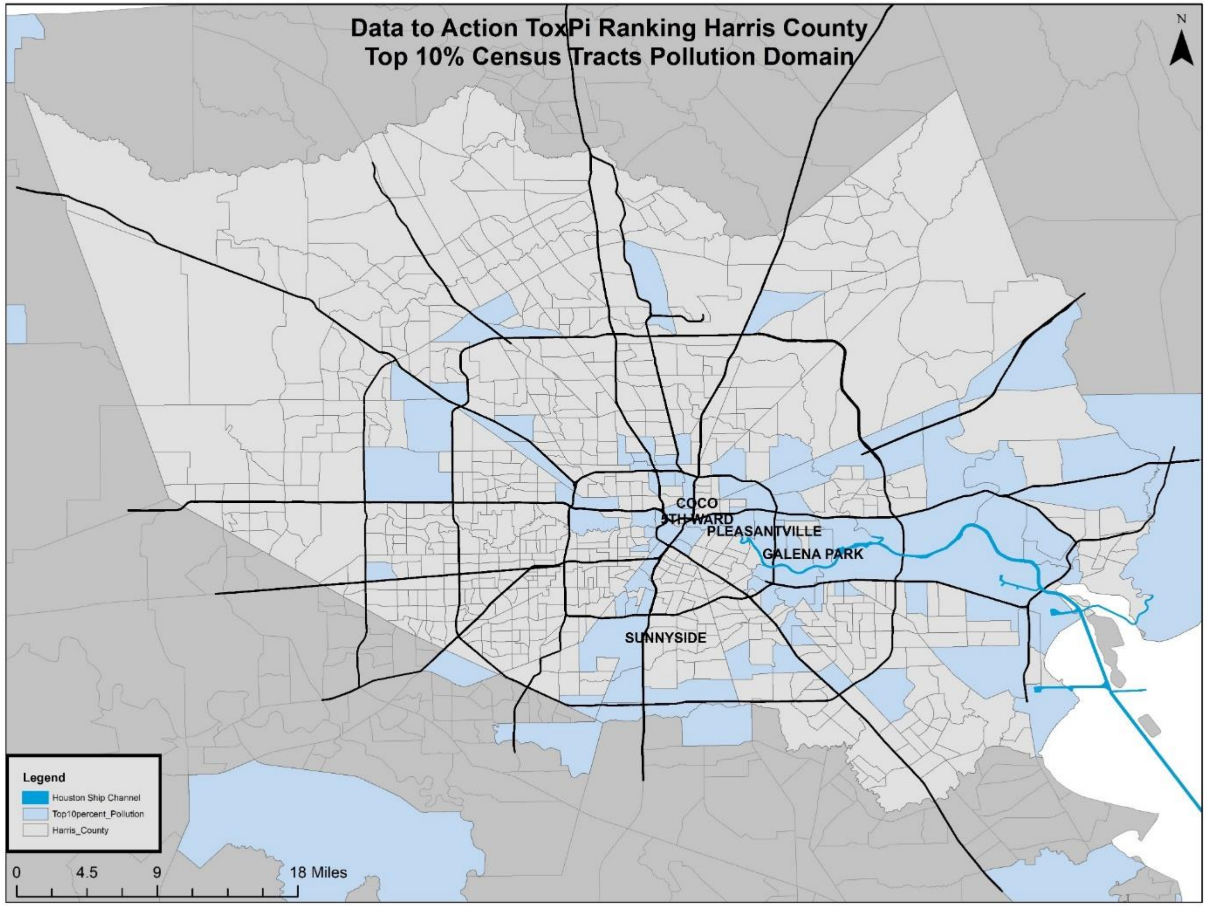
Domain Specific Visualizations





Domain Specific Visualizations





Transportation Planning

- Incorporate air quality and health considerations
  - Air pollution: Health and climate impacts
  - Transportation emissions and population exposures collocated in urban areas
- Scientific, data driven approach
- HGAC region at census tract resolution
- Prioritizing communities with greatest cumulative burdens
- Scalable

Environment International 130 (2019) 104909

Contents lists available at ScienceDirect

Environment International

journal homepage: www.elsevier.com/locate/envint

An ensemble-based model of $PM_{2.5}$ concentration across the contiguous United States with high spatiotemporal resolution

Qian Di[a,b,*], Heresh Amini[a], Liuhua Shi[a], Itai Kloog[c], Rachel Silvern[d], James Kelly[e], M. Benjamin Sabath[f], Christine Choirat[f], Petros Koutrakis[a], Alexei Lyapustin[g], Yujie Wang[h], Loretta J. Mickley[i], Joel Schwartz[a]

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PM2.5 Ensemble Data
Methodology

EDF Blogpost
http://blogs.edf.org/health/2020/05/11/pm-standards-houston-analysis/

Ensemble Model to Predict Overall $PM_{2.5}$

Predictor Variables

- *AOD Measurements and Other Satellite Data*
- *Chemical Transport Model*
- *Land-Use Variables*
- *Meteorological Variables*

Spatial and Temporal Autocorrelation to improve model performance: Use nearby monitoring site and neighboring days

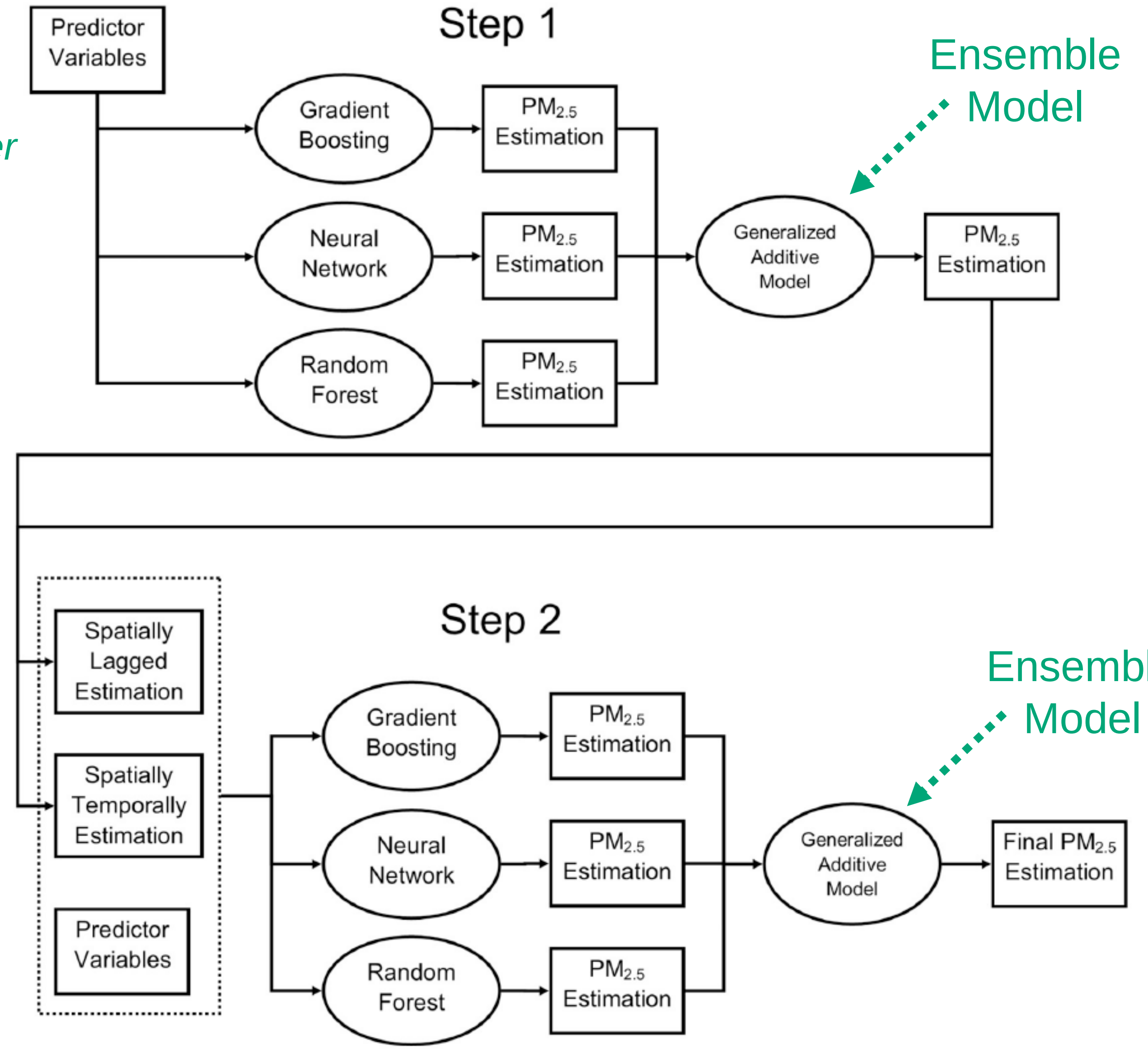


Fig. 1. Flowchart of model training process.

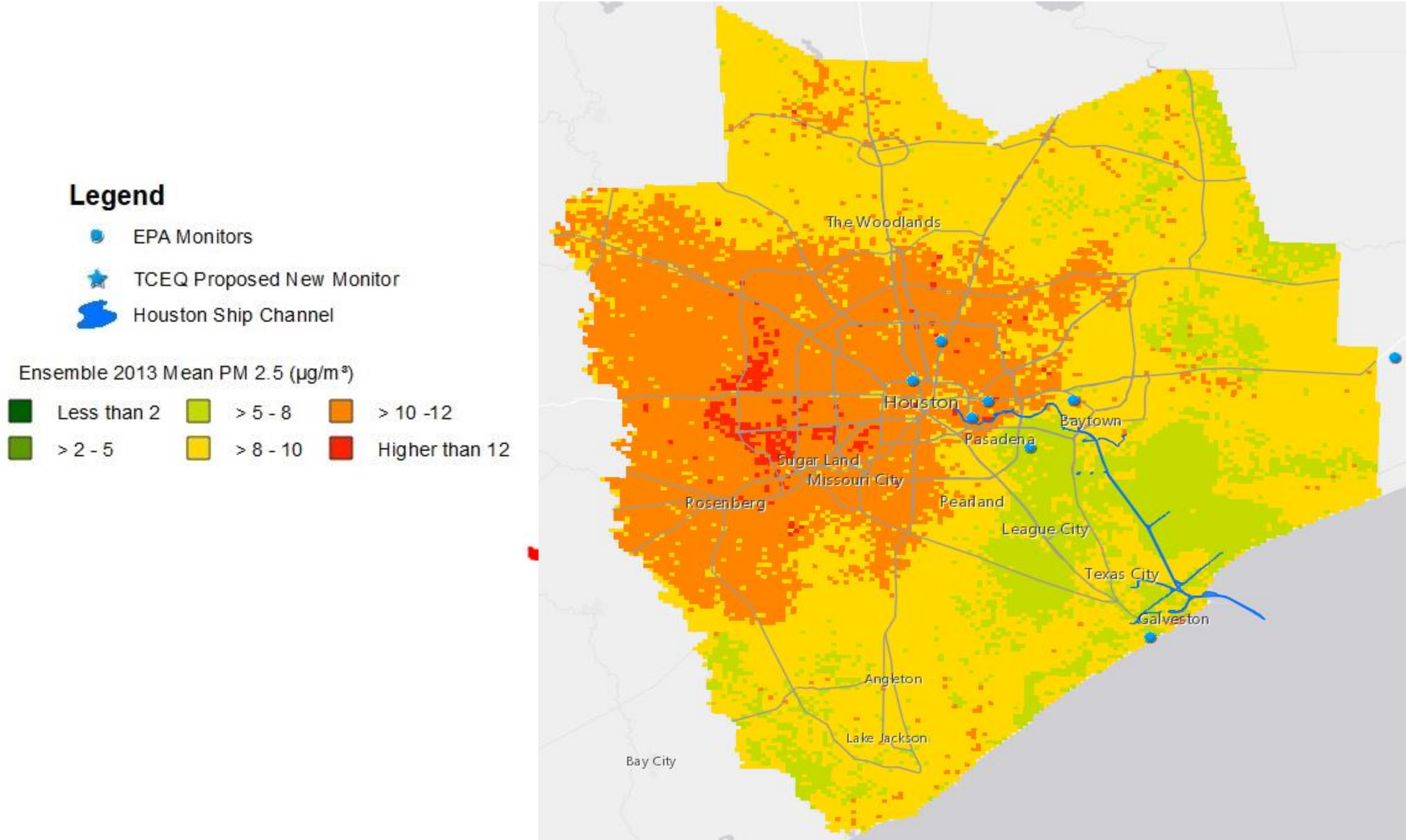
Ensemble Model

Ensemble Model

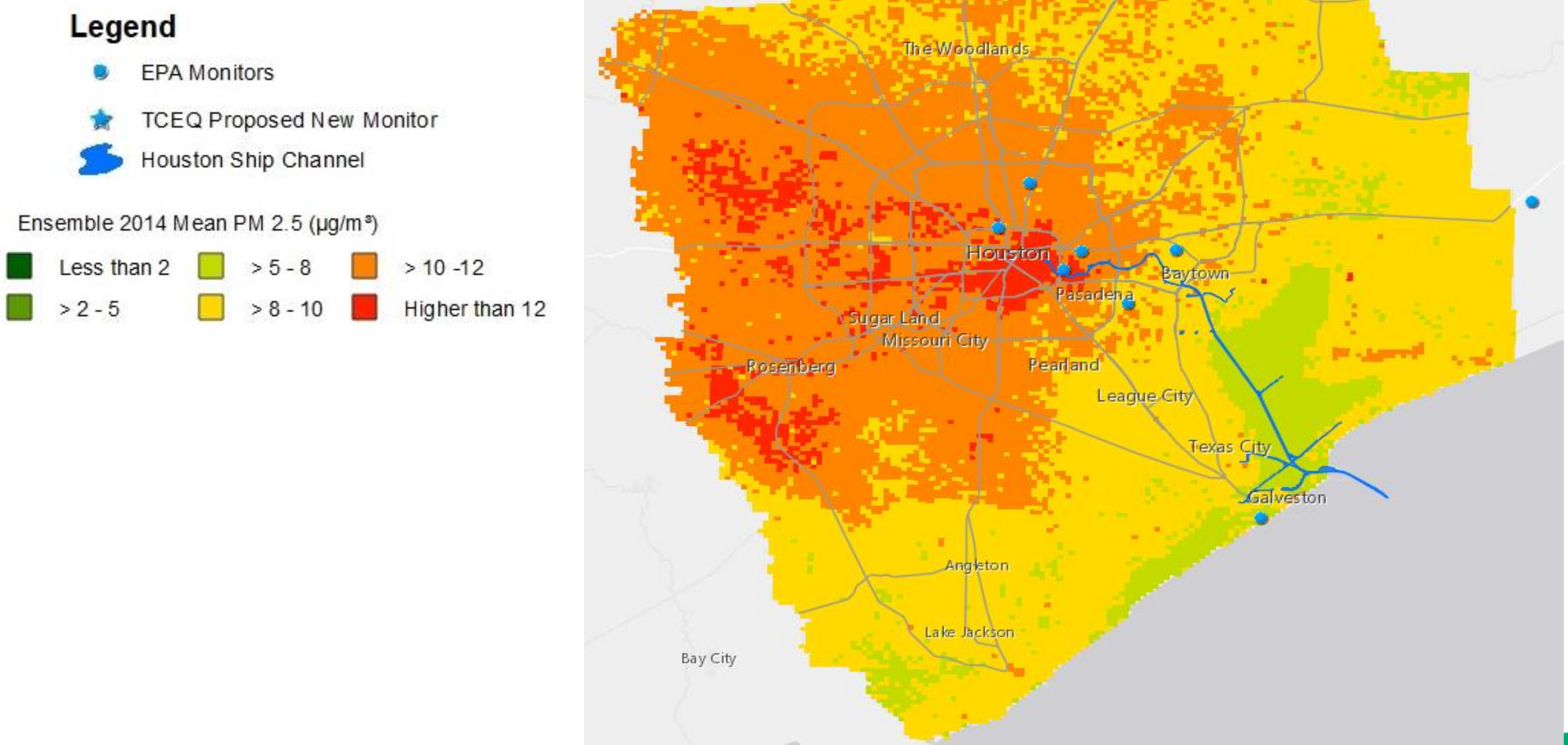
Entire USA 2000-2015

Di et al. Environment International 130 (2019)

HGB $PM_{2.5}$ Concentration ($\mu g/m^3$), 2013



HGB $PM_{2.5}$ Concentration ($\mu g/m^3$)2014



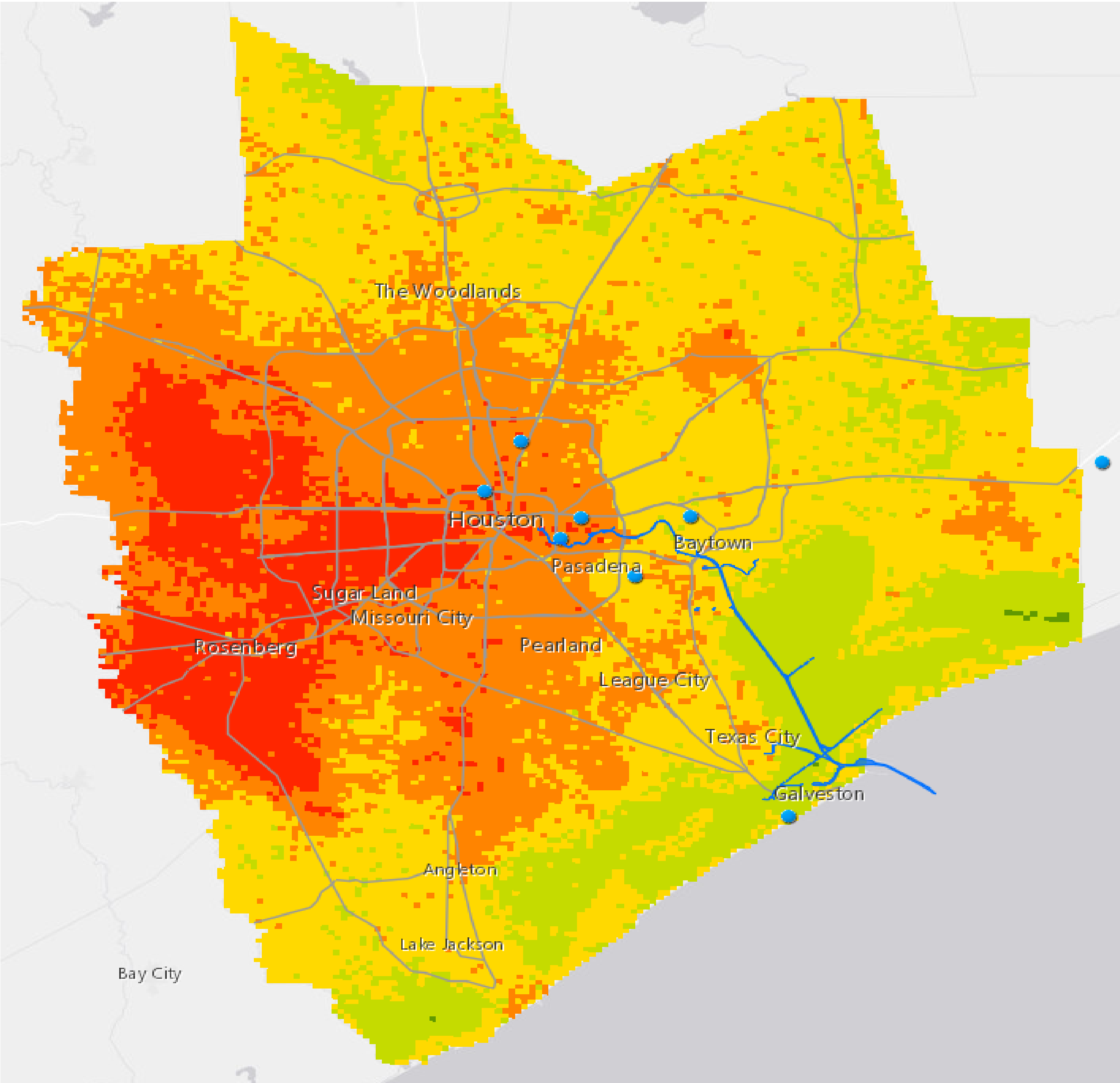
HGB $PM_{2.5}$ Concentration (µg/m³), 2015

Legend

- EPA Monitors
- TCEQ Proposed New Monitor
- Houston Ship Channel

Ensemble 2015 Mean PM 2.5 (µg/m³)

- Less than 2
- > 2 - 5
- > 5 - 8
- > 8 - 10
- > 10 -12
- Higher than 12



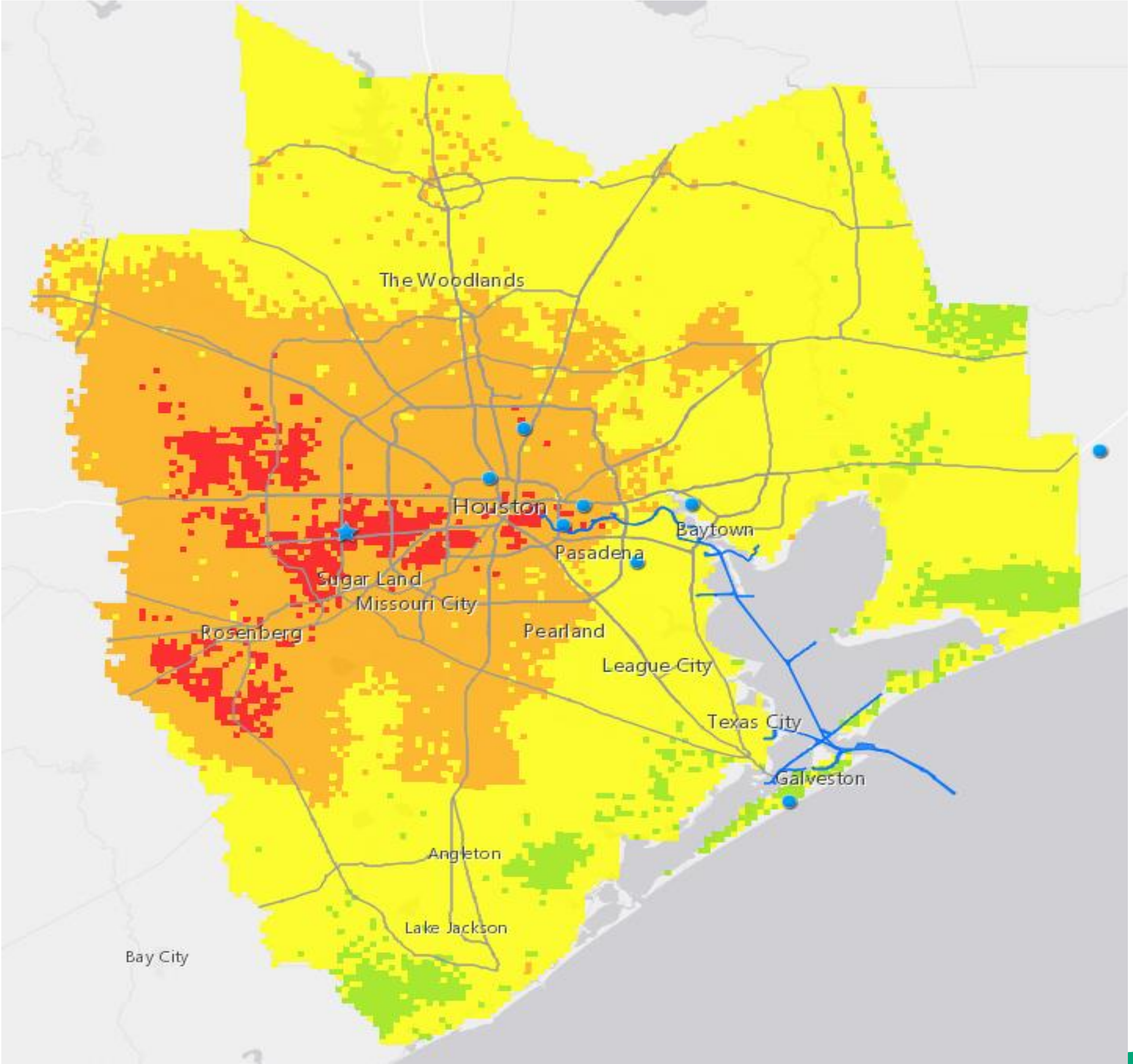
HGB $PM_{2.5}$ Annual Average ($\mu g/m^3$), 2013-2015

Legend

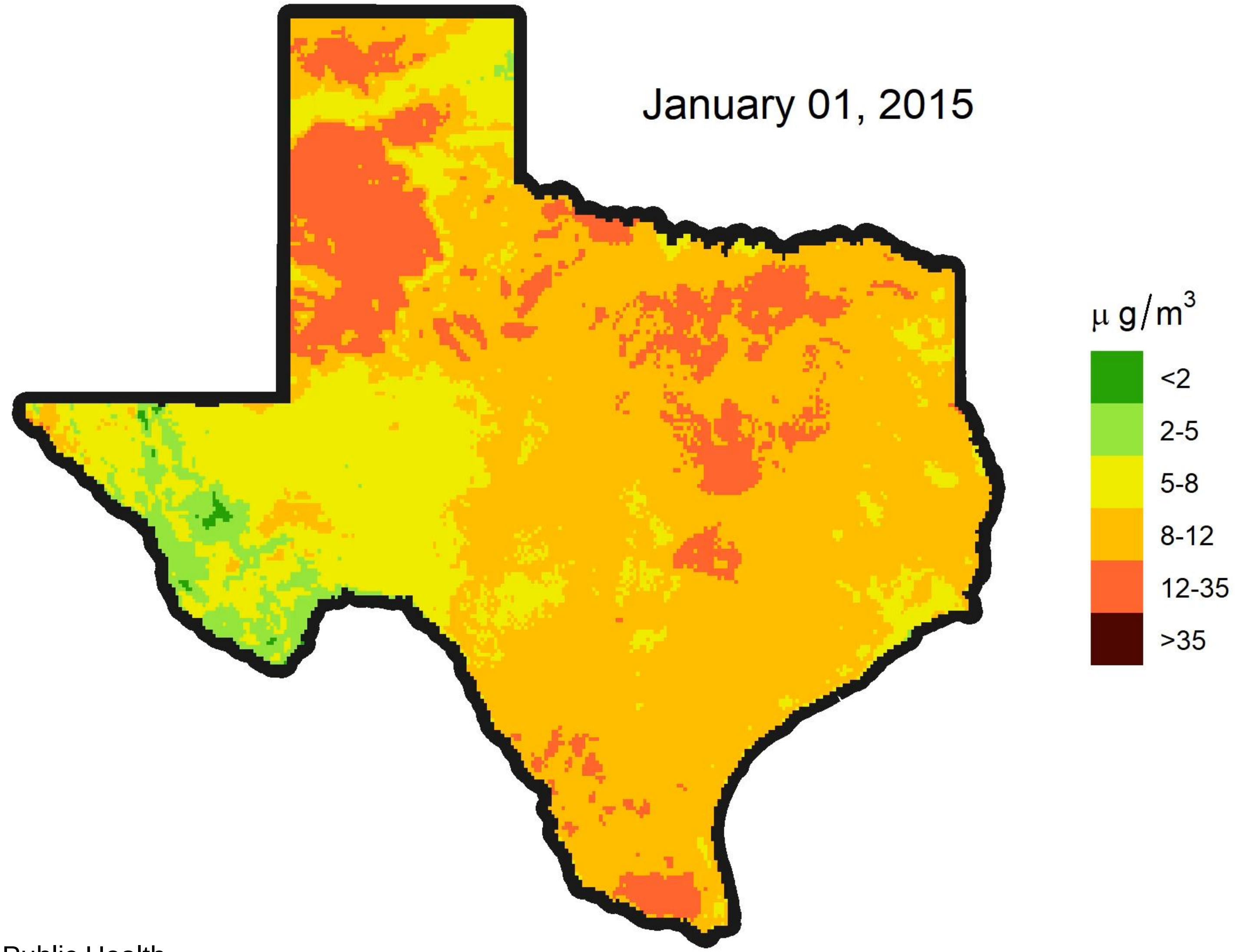
- EPA Monitors
- TCEQ Proposed New Monitor
- Houston Ship Channel

Mean PM 2.5 (2013 - 2015), $\mu g/m^3$

- less than 2
- 2.1 - 5
- 5.1 - 8
- 8.1 - 10
- 10.1 - 12
- over 12



$PM_{2.5}$ in Texas, 2015



Data Source: Harvard TH Chan School of Public Health
Di et al. Environment International 130 (2019)

Environmental Research 166 (2018) 677–689

Contents lists available at ScienceDirect

Environmental Research

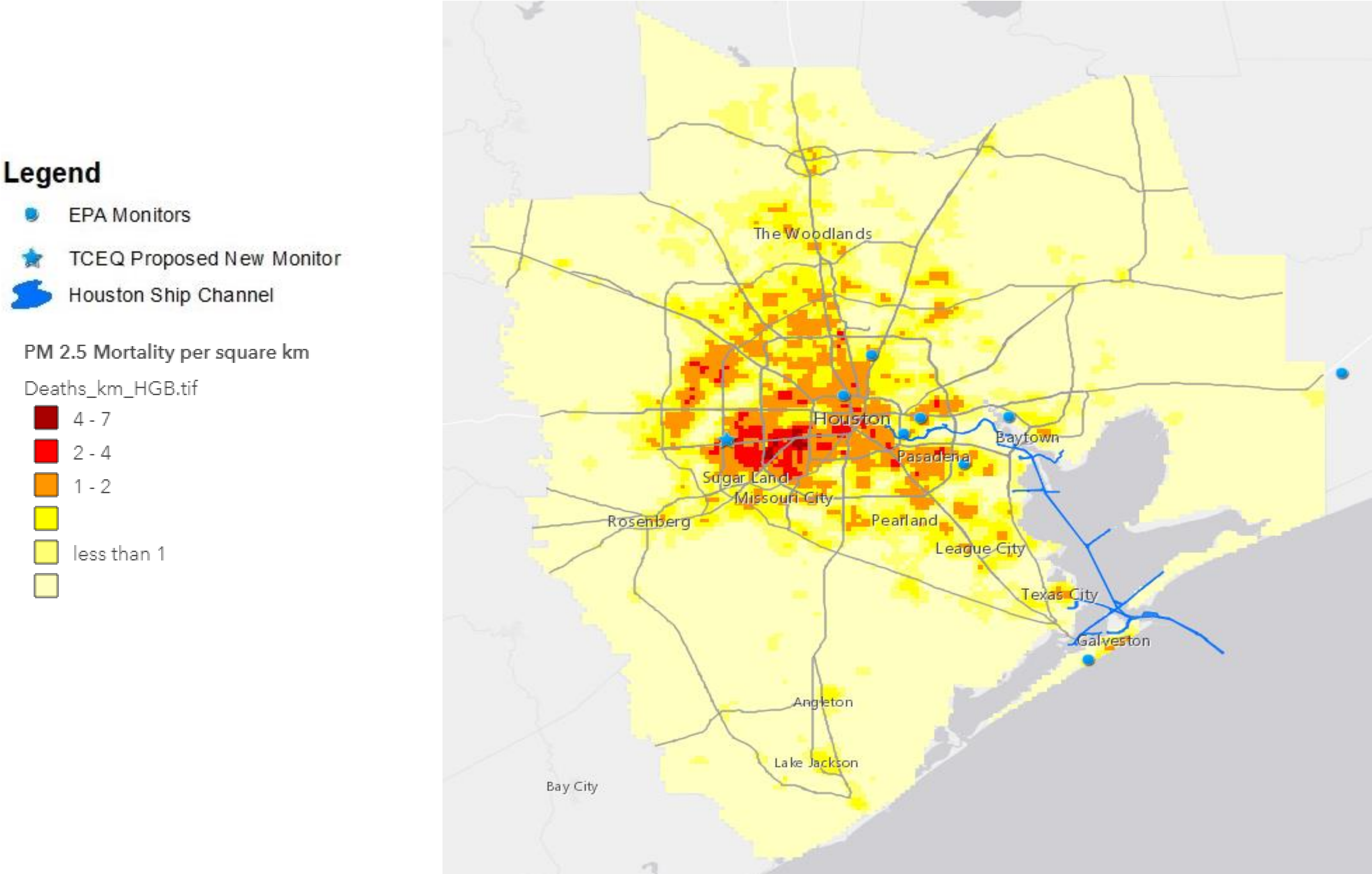
journal homepage: www.elsevier.com/locate/envres

The concentration-response between long-term $PM_{2.5}$ exposure and mortality; A meta-regression approach

Alina Vodonos*, Yara Abu Awad, Joel Schwartz

Department of Environmental Health, Harvard T.H. Chan School of Public Heath, Boston, MA 02115, USA

Distribution of PM2.5 Attributable Deaths (2015)



Zoom In View of PM2.5 Attributable Deaths

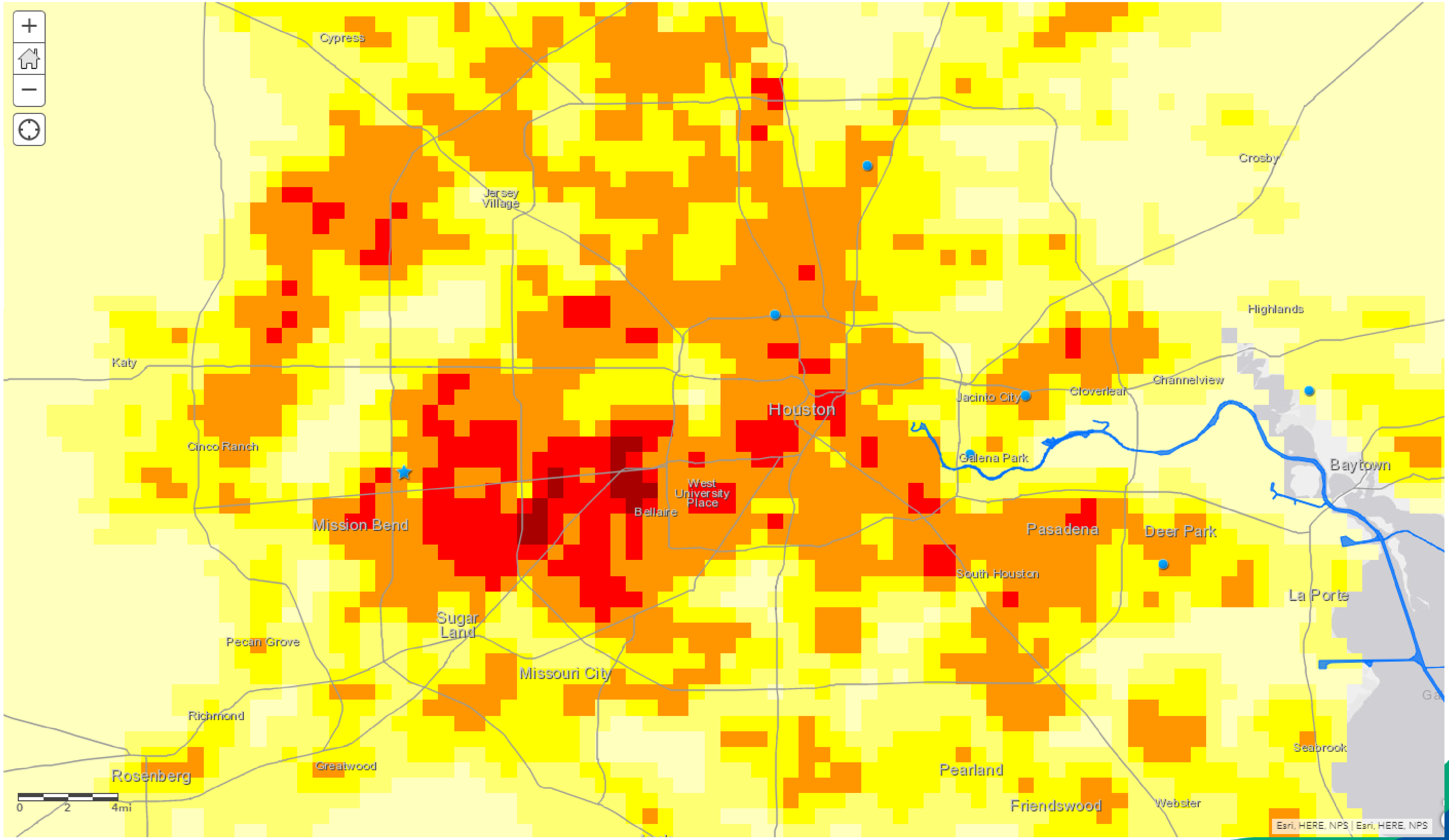
Legend

- EPA Monitors
- TCEQ Proposed New Monitor
- Houston Ship Channel

PM 2.5 Mortality per square km

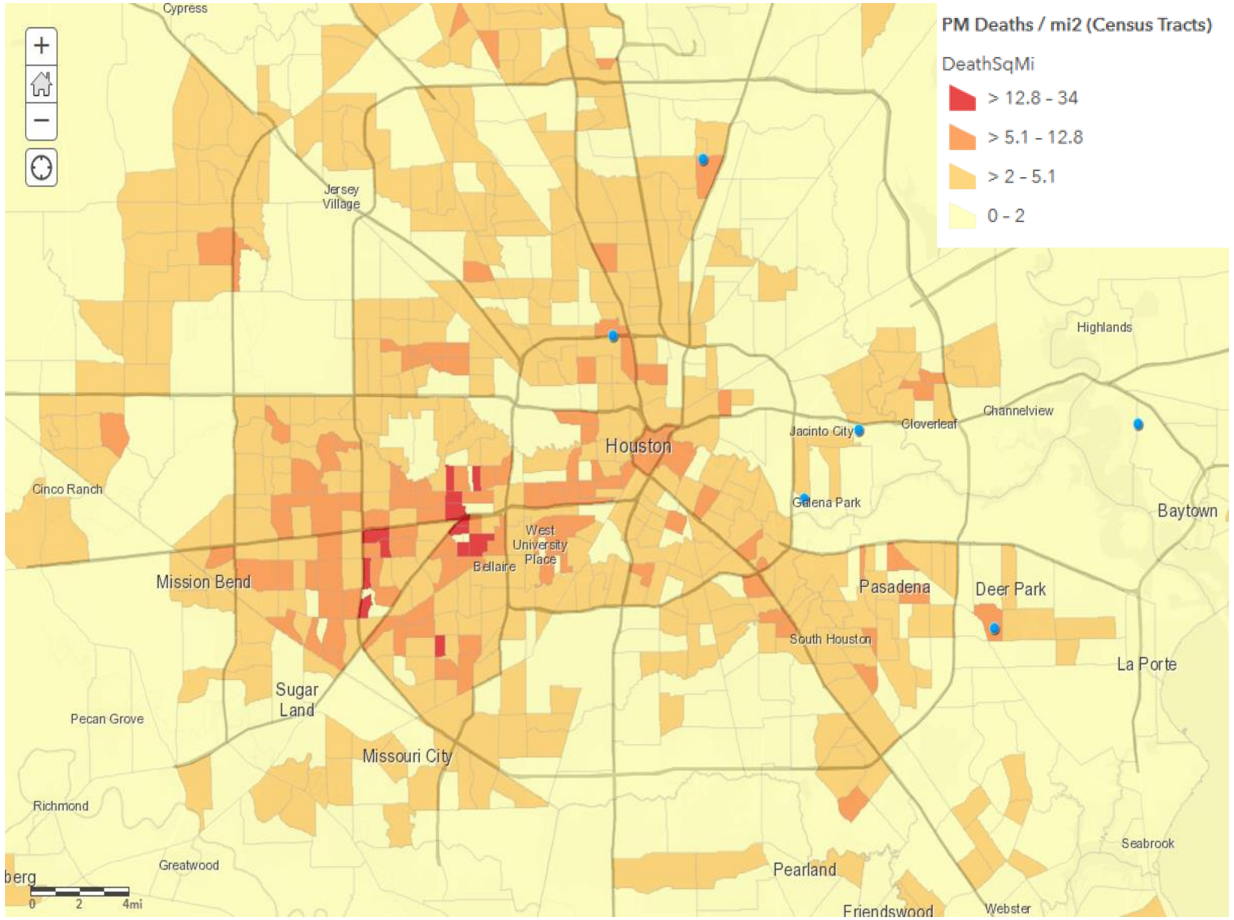
Deaths_km_HGB.tif

- 4 - 7
- 2 - 4
- 1 - 2
- less than 1

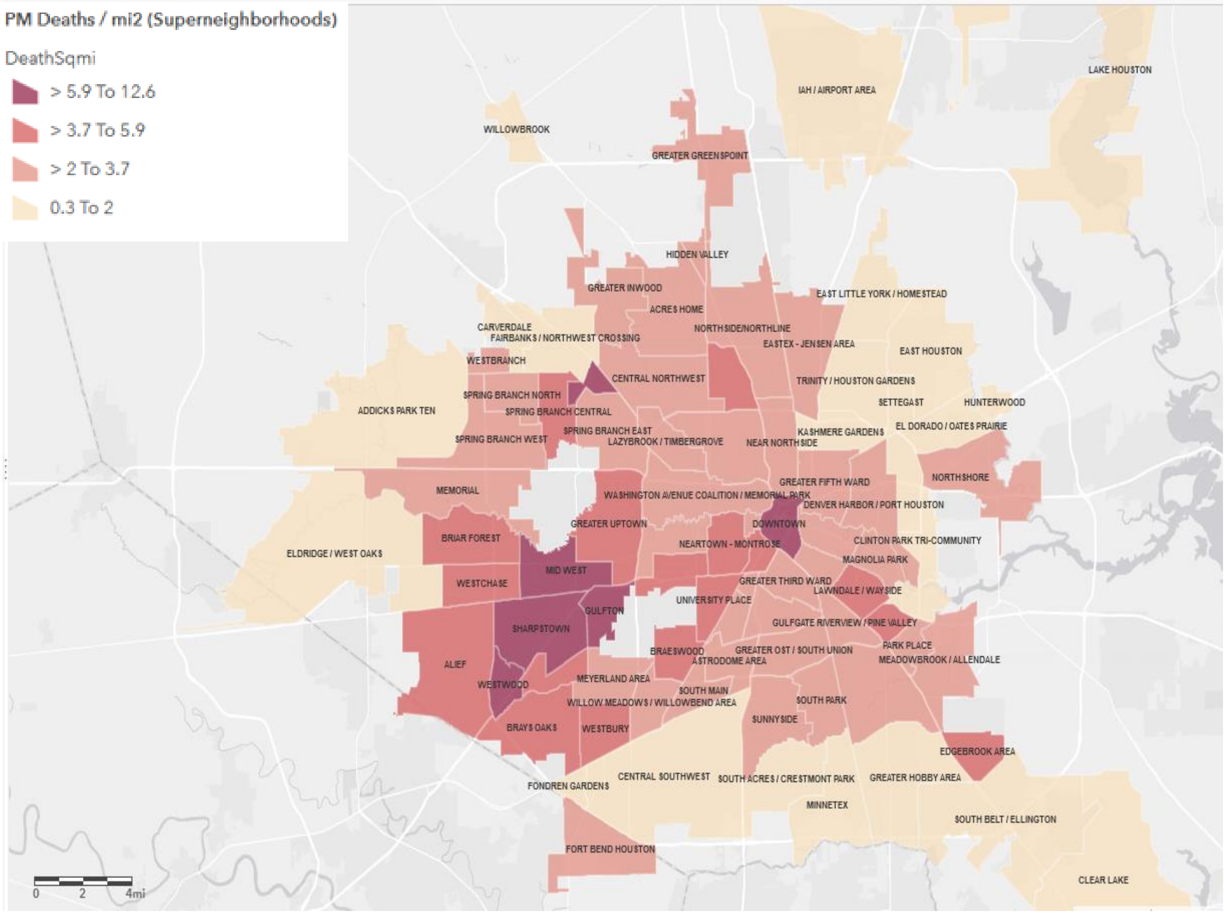


HGB $PM_{2.5}$ Attributable Deaths (2015)

By Census Tract



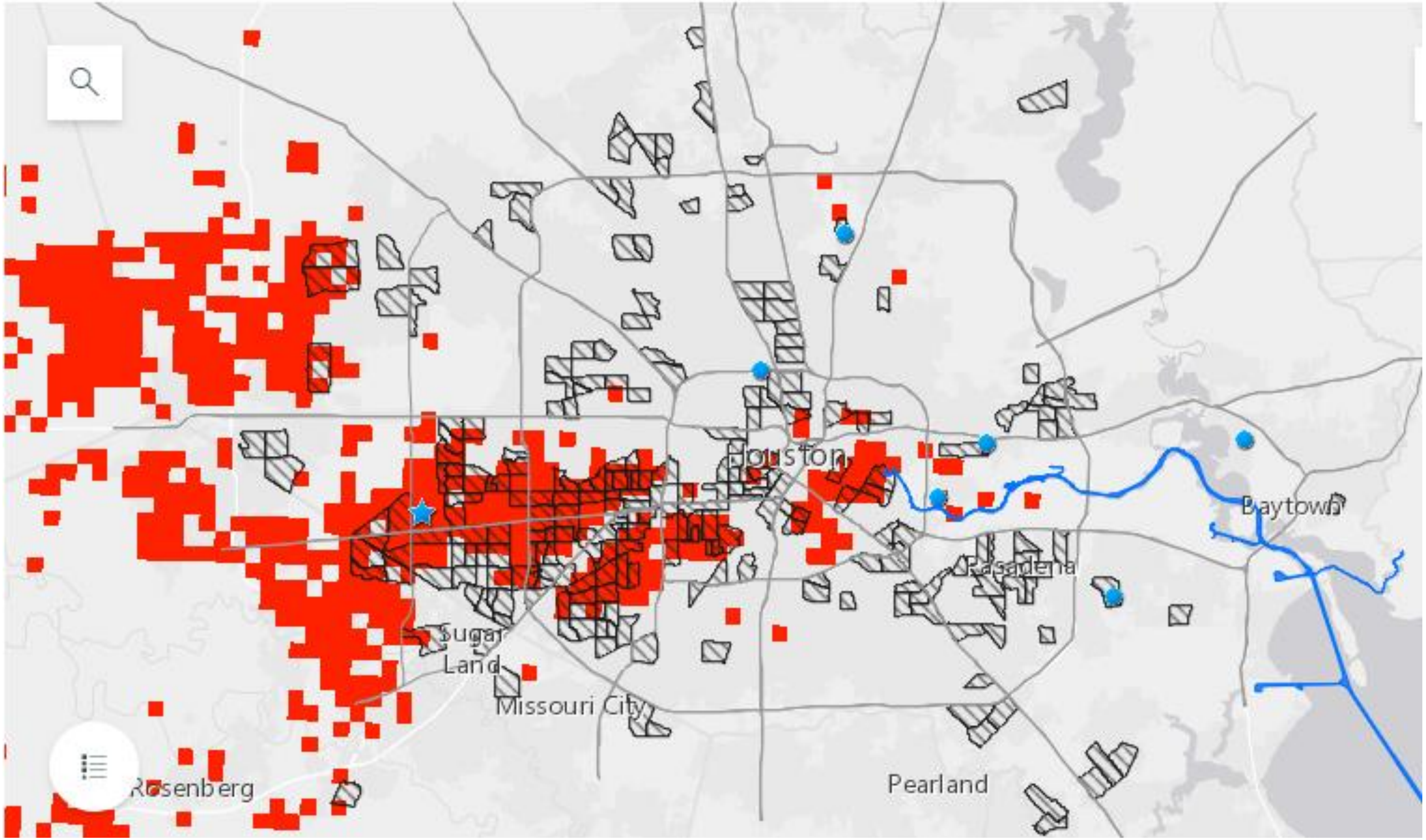
By Super Neighborhood



Population Density and PM2.5 levels Above Annual NAAQS

Legend

- EPA Monitors
- TCEQ Proposed New Monitor
- Houston Ship Channel
- Population density greater than 5,700 people per square mile
- Mean PM 2.5 (2013-2015) greater than 12 µg/m³



Proposed Location of New $PM_{2.5}$ Monitor

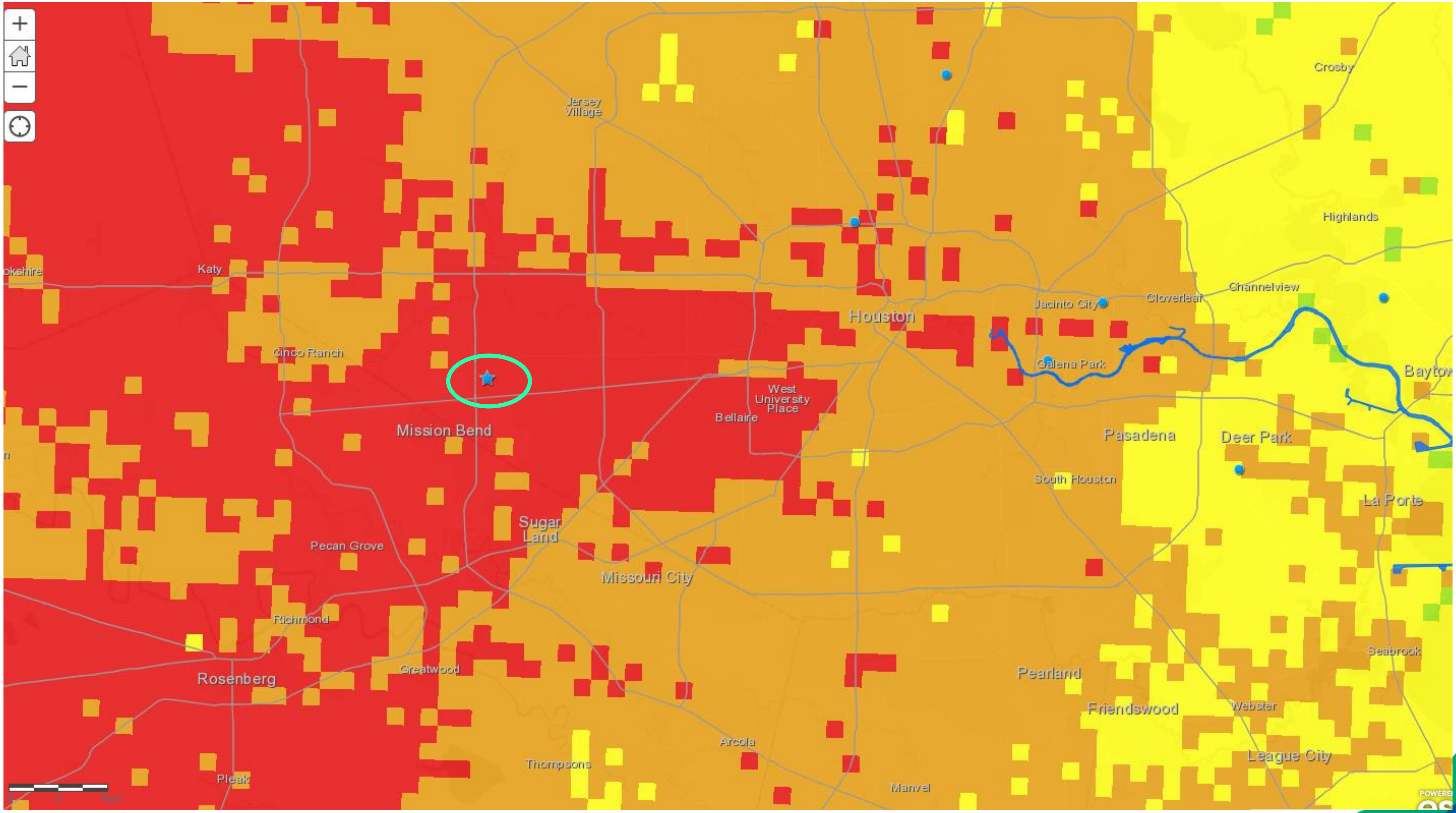
Legend

- EPA Monitors
- TCEQ Proposed New Monitor
- Houston Ship Channel

2015 Mean PM 2.5

Mean

- Higher than 12
- > 10 - 12
- > 8 - 10
- > 5 - 8
- 3.95 - 5



P. Grace Tee Lewis, PhD
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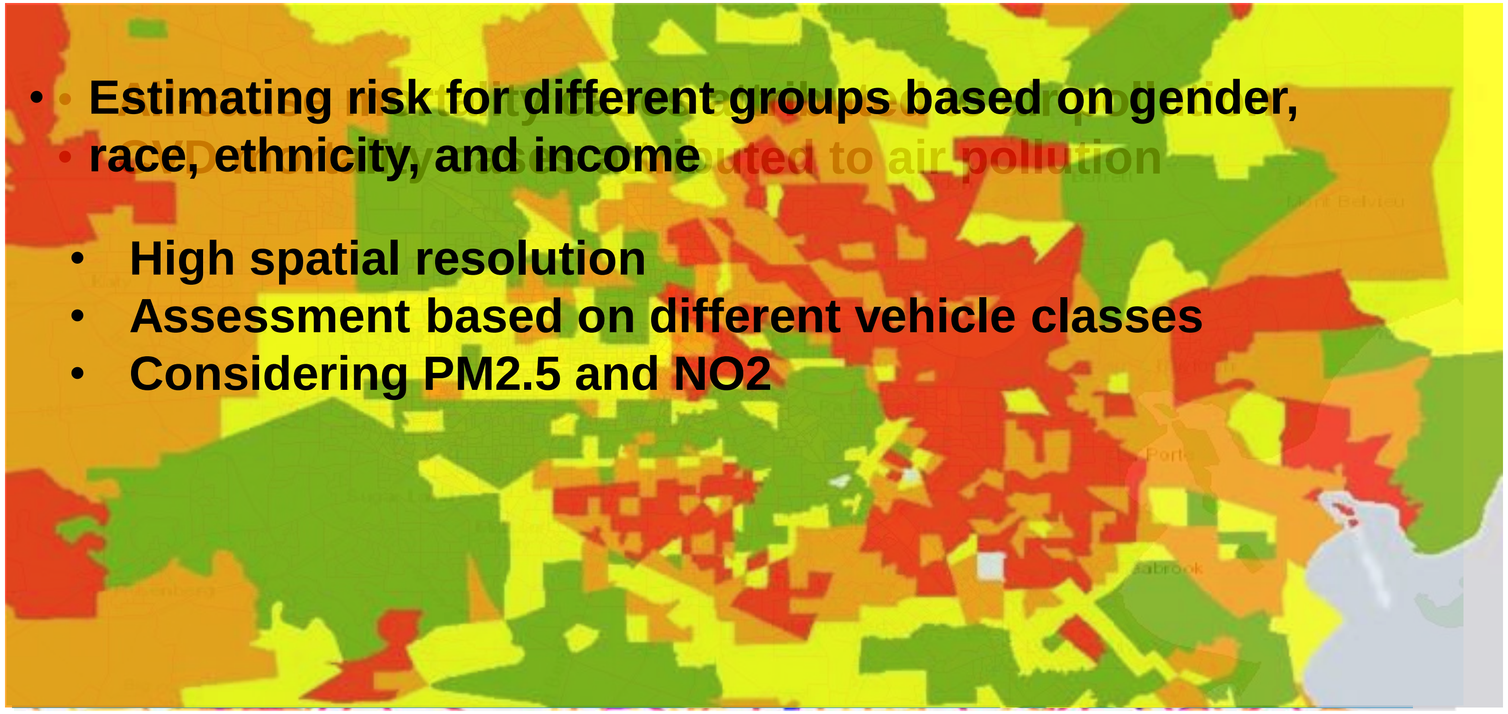
Advanced Fine Scale Transportation, Air Quality, Health Integrated Assessment Tool for Future Cities

Mahnaz Nadaf. Ph.D

EDF-Cornell Post-doc Fellow

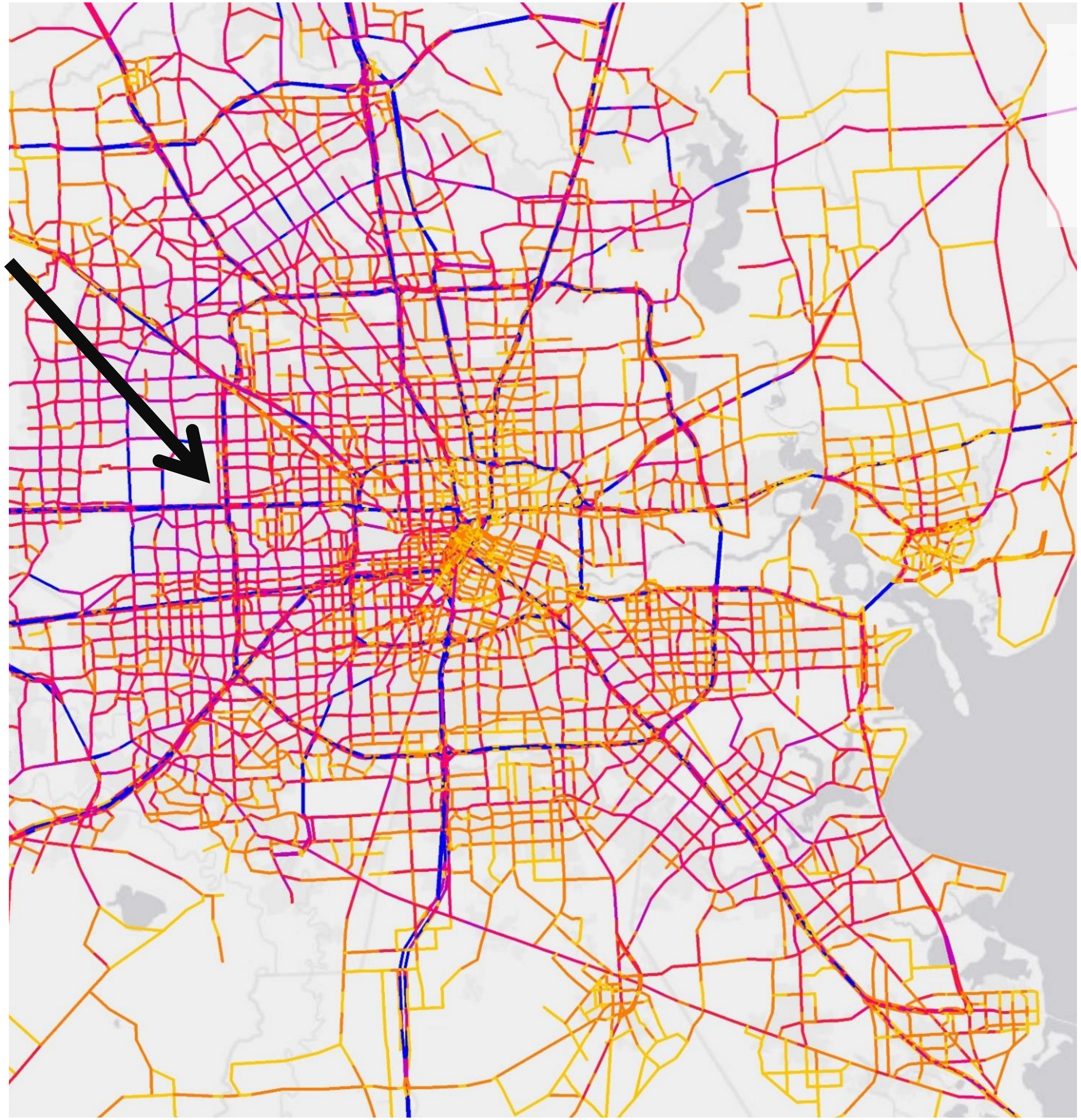
From Transportation Planning To Health Impact Assessment:
Integrated Modeling Framework

- Estimating risk for different groups based on gender, race, ethnicity, and income
  - High spatial resolution
  - Assessment based on different vehicle classes
  - Considering PM2.5 and NO2

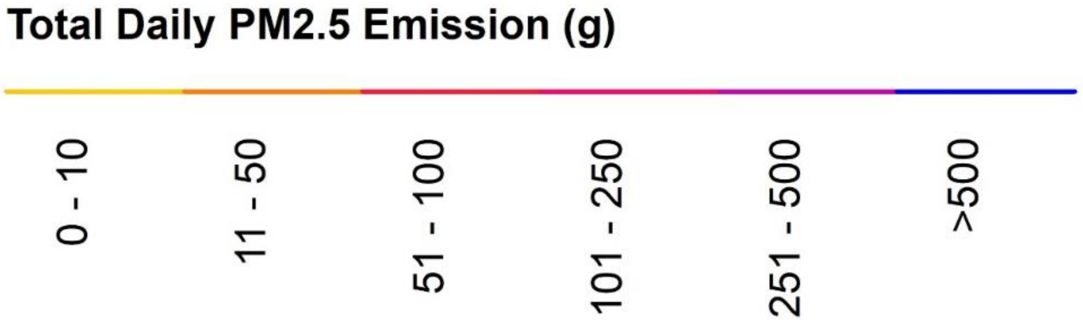


Transportation Planning → Emission Analysis → Air Dispersion → Exposure Analysis → Health Impact Assessment → Disparity Analysis

Primary PM2.5 Emission at Link Level

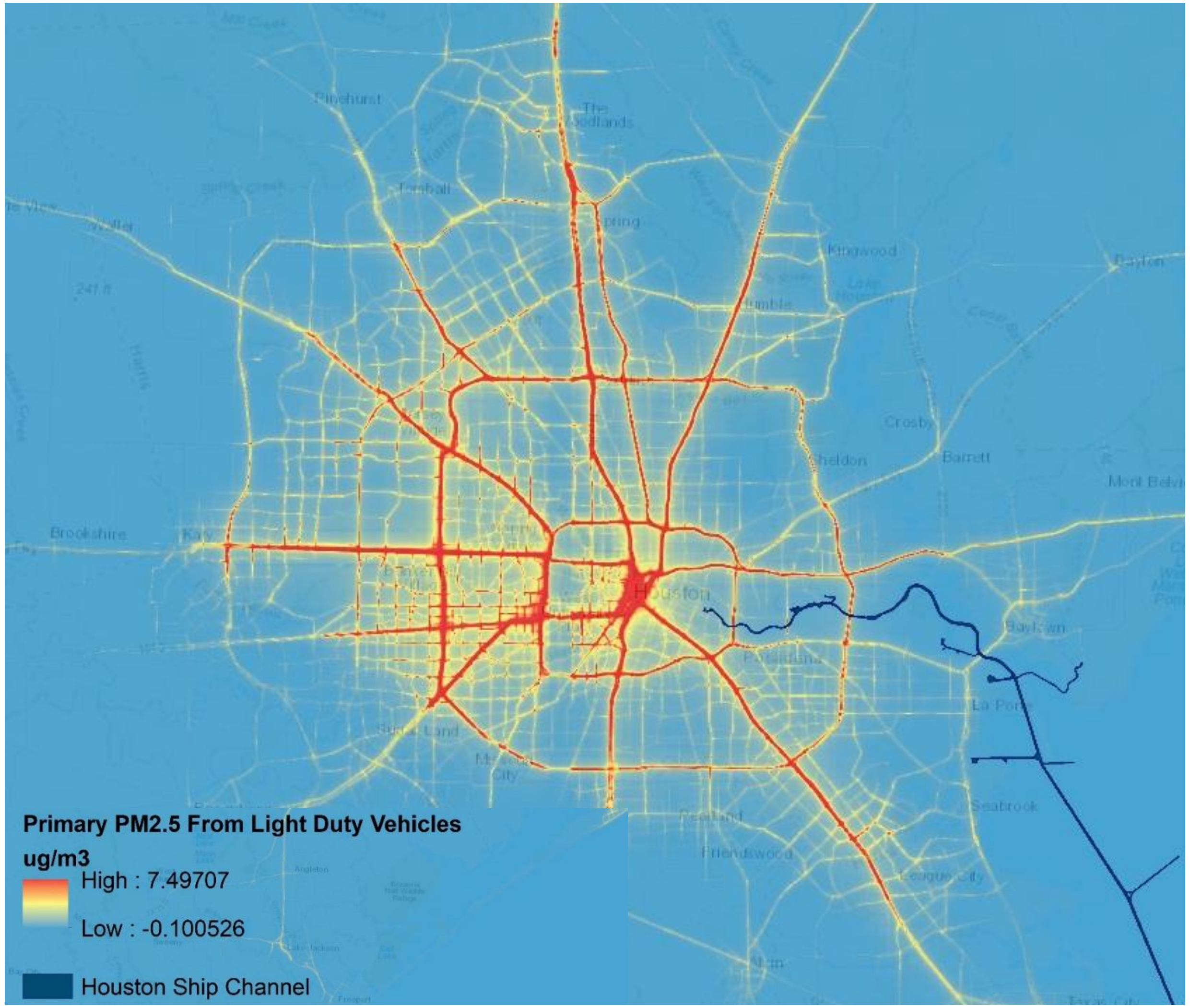


- VMT= 180 Millions
- Primary PM2.5= 4 Tones
- NOx=77 Tones

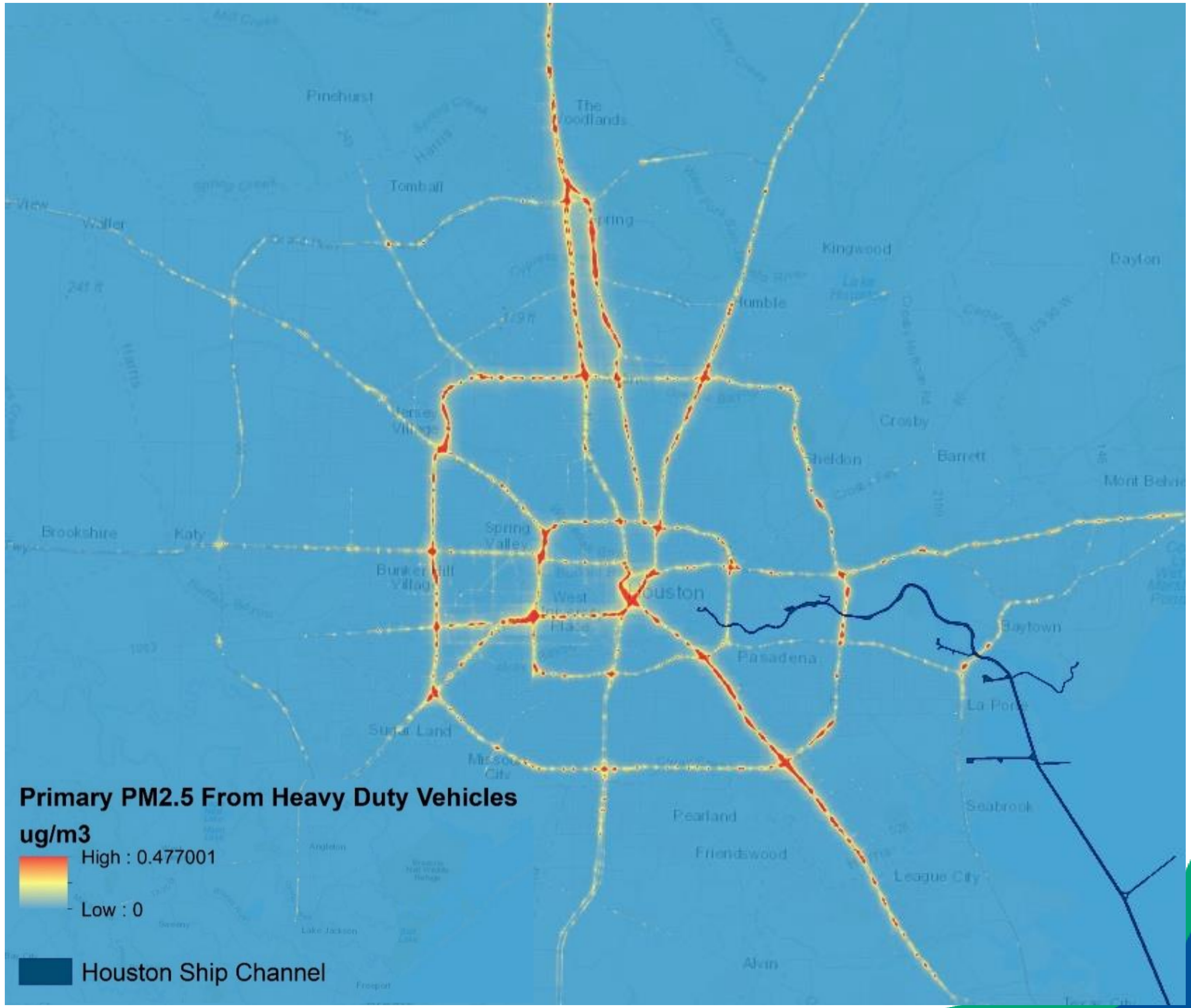


Concentration of Primary PM2.5: Light Duty vs Heavy Duty Vehicles

Primary PM2.5 from Light Duty Vehicles
Max: 7.49 μg/m3



Primary PM2.5 from Heavy Duty Vehicles
Max: 0.47 μg/m3



Exposure to Primary PM2.5 and Disparities

- Those of the lowest income experience **43.3%** higher exposure to vehicle emissions compared to highest income group.

- African-American people have **10.6%** higher exposure compared to White people.

- Latinos bear a disproportionate, **17.1%** higher, burden from air pollution compared to non-Latinos.

- Low incomes, non-whites, and Latinos are more likely to live closer to highways as compared to other income, race, and ethnicity groups.

EFFECTS OF COVID-19 ON TRANSPORTATION and AIR QUALITY

Air Quality Health Monitoring Taskforce Meeting

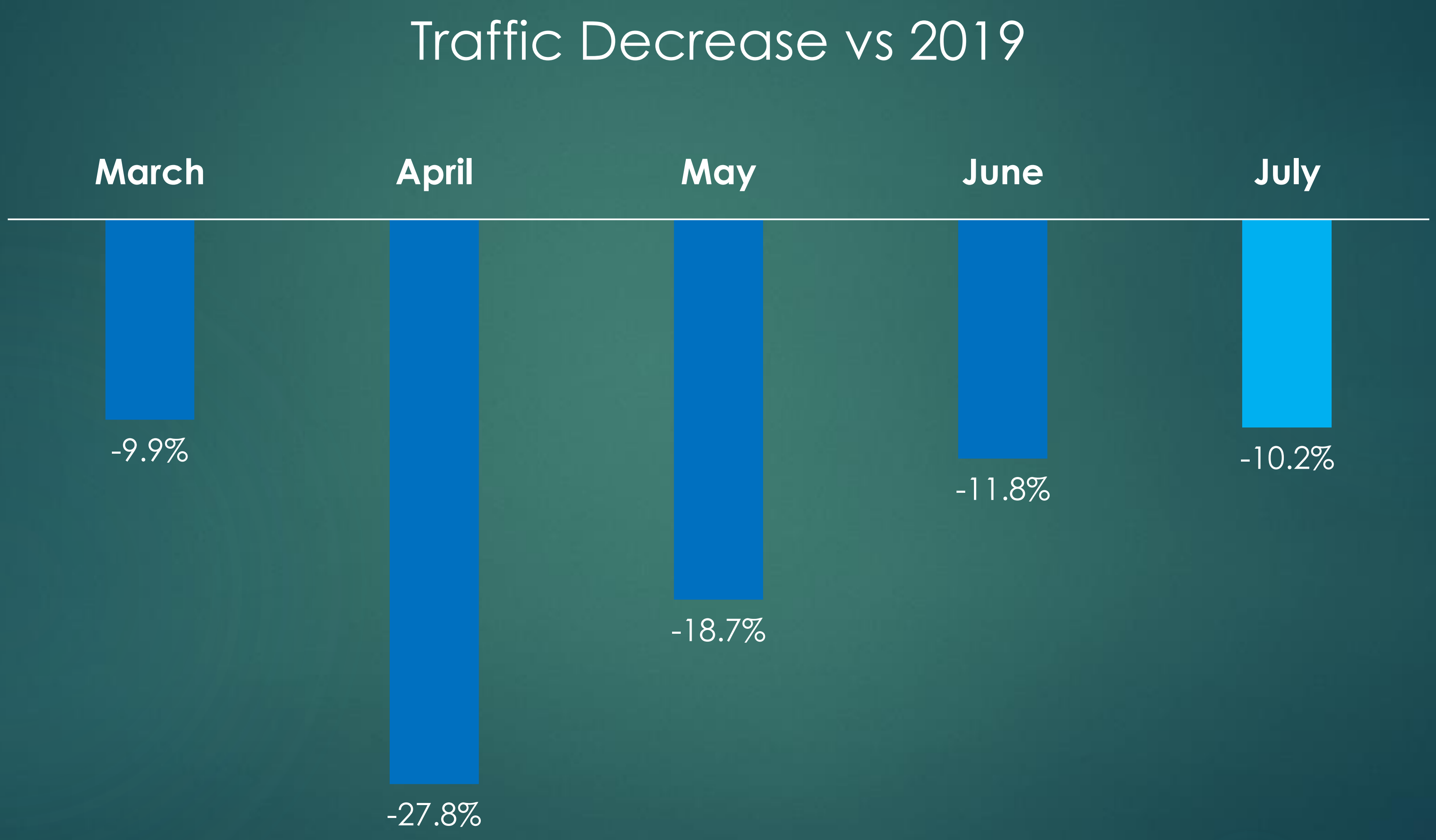
August 21, 2020

Nick Van Haasen

North Central Texas
Council of Governments

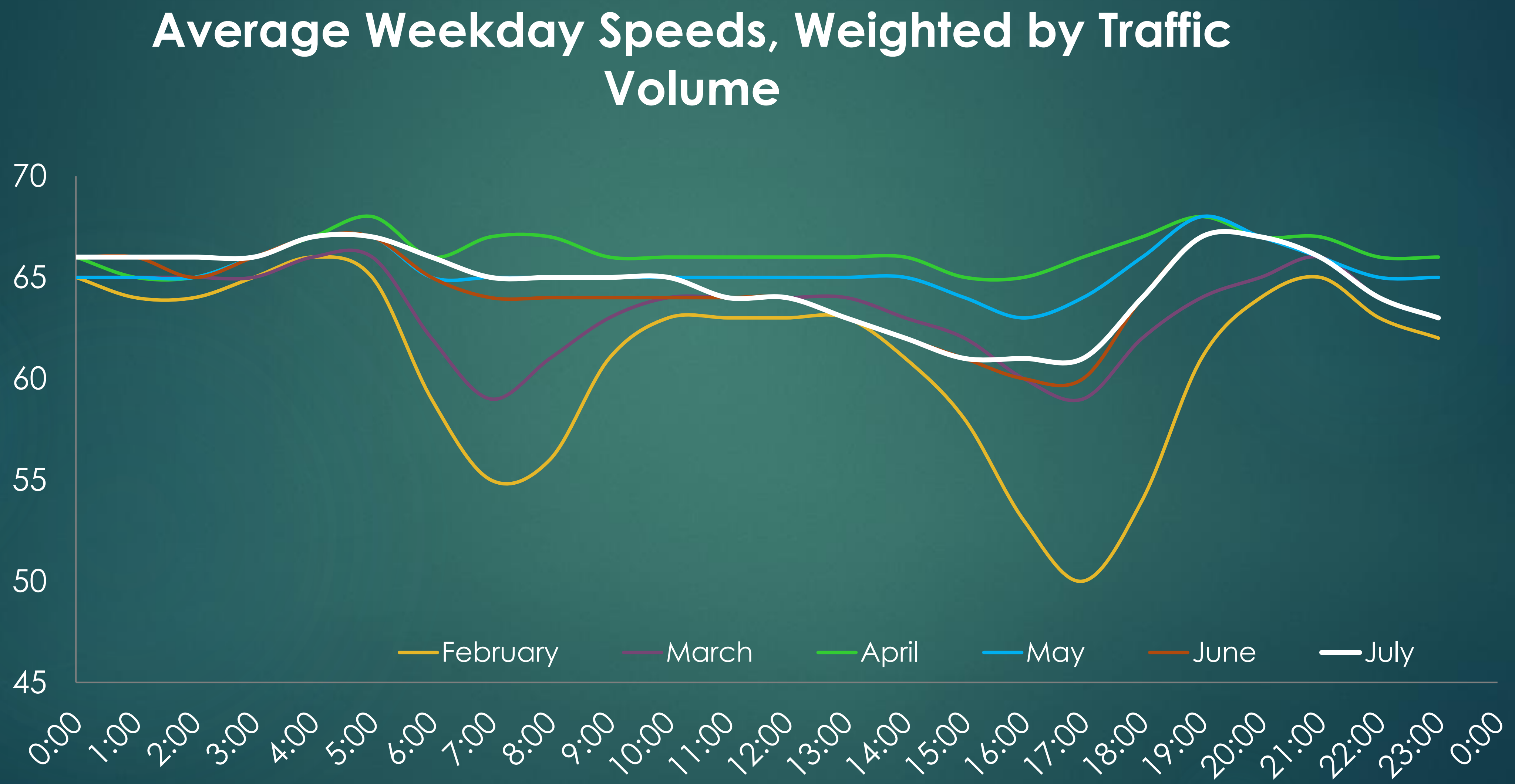
1. TRANSPORTATION

Weekly Freeway Volumes: Respective 2019 to 2020



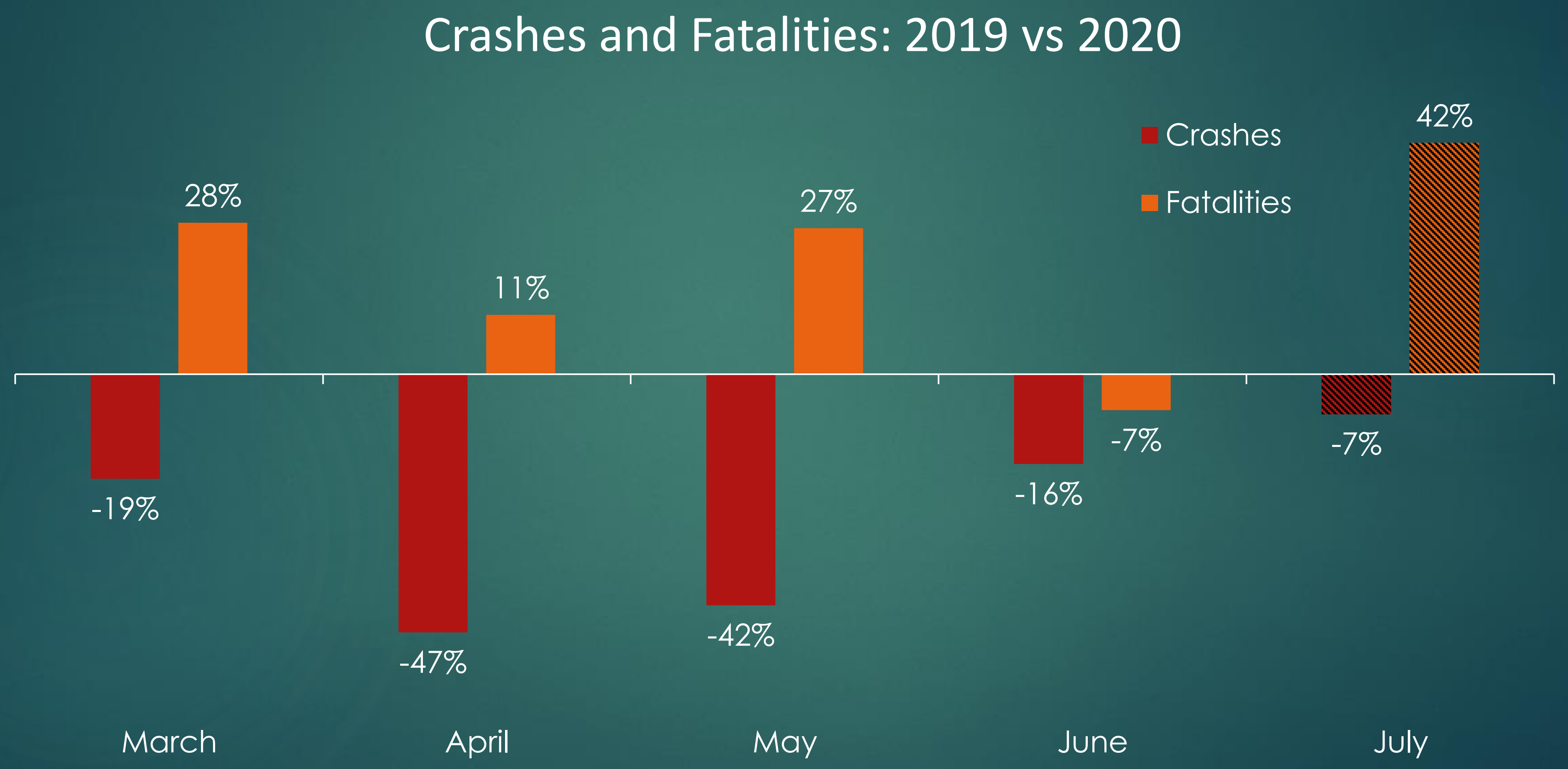
Source: Traffic Radars on TxDOT Dallas and Fort Worth Districts

Regional Average Freeway Speed By Time of Day



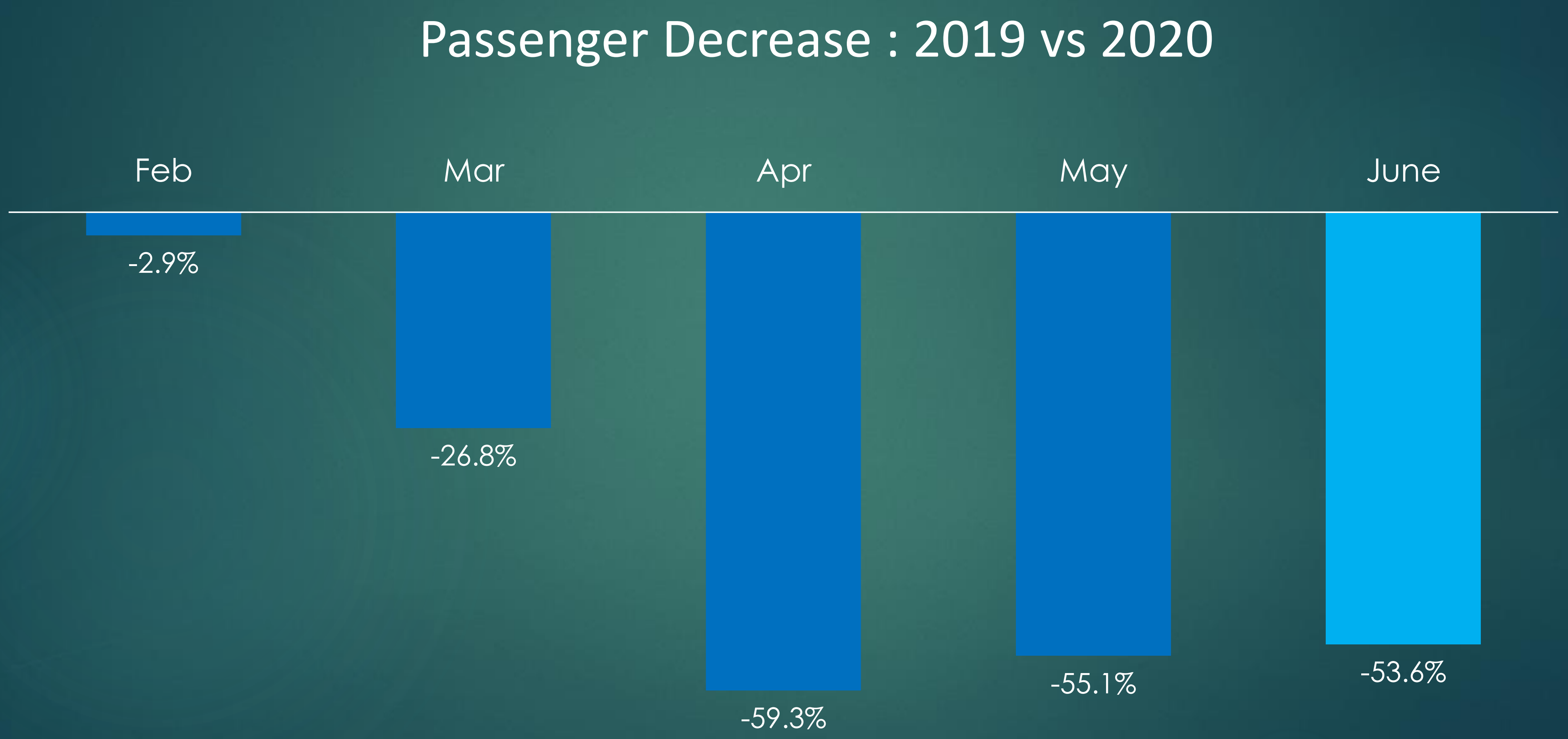
Source: TxDOT Sidefire Devices

Percentage of Crashes: March and April 2019 vs March and April 2020



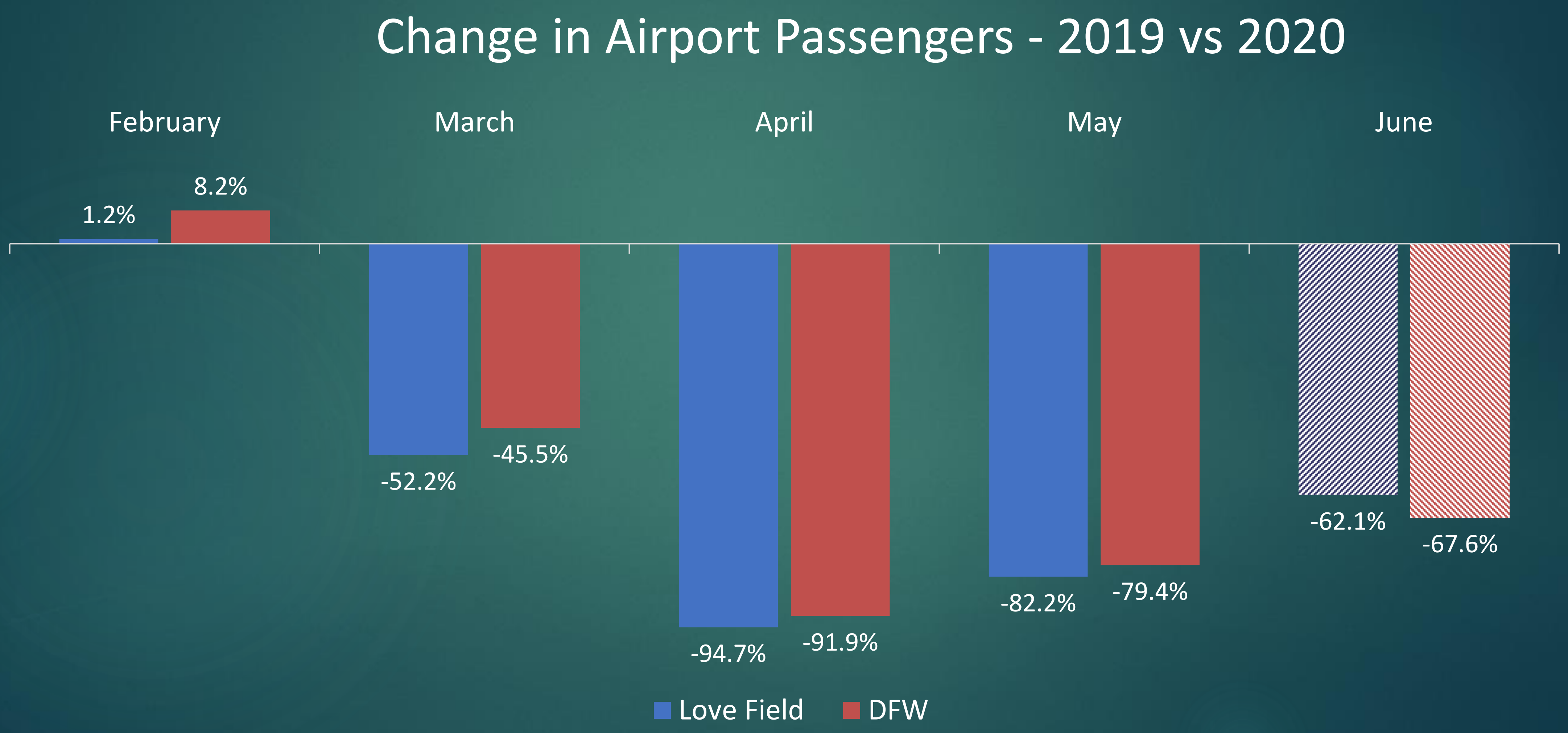
Source: TxDOT Crash Records Information System

Transit Impacts: Ridership



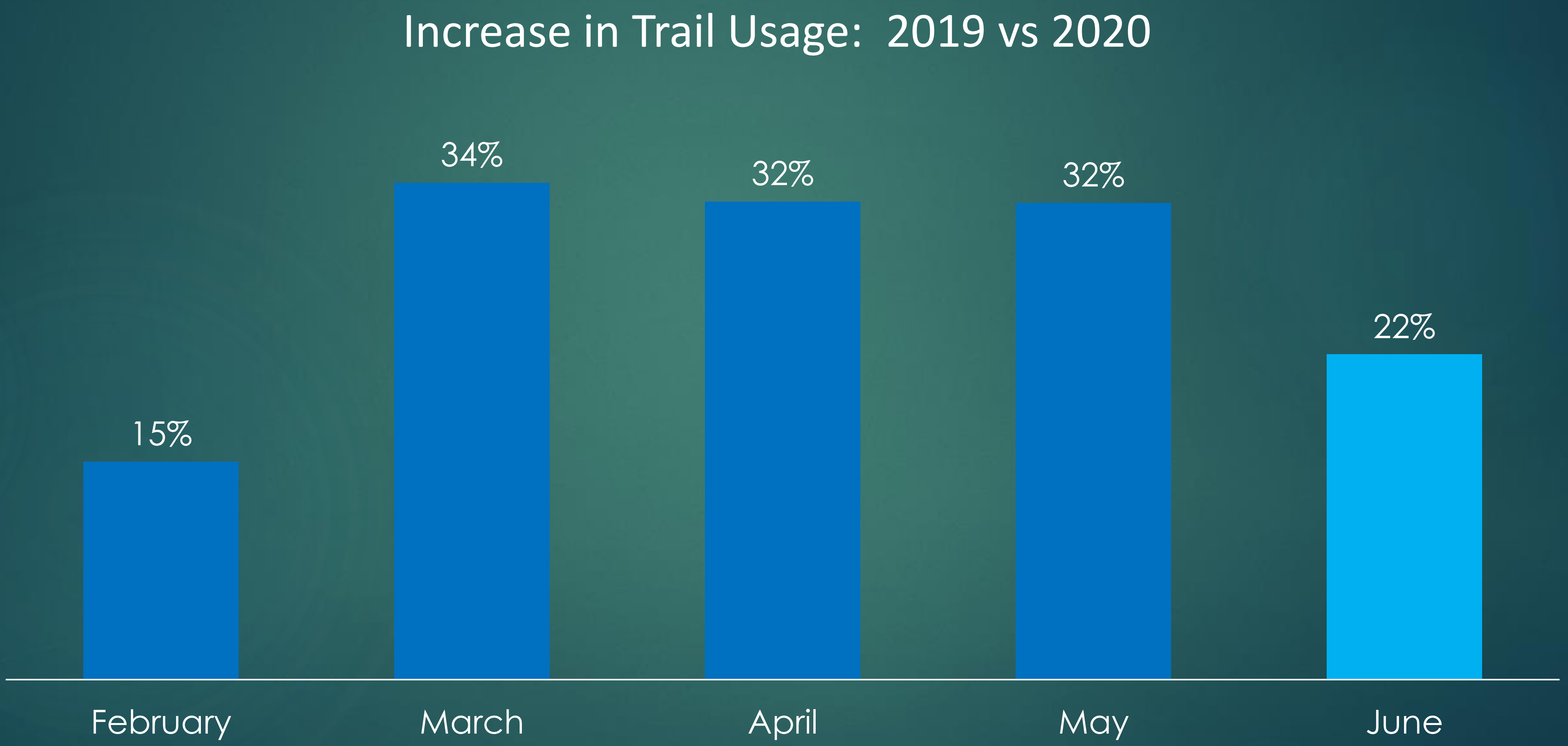
Source: DART, DCTA, and Trinity Metro

Airport Impacts: Passenger Trends



Source: Dallas Love Field Website and DFWIA data

Bicycle and Pedestrian Impacts: Trail Counts



Source: NCTCOG, collected at Chisholm Trail in Plano, Denton Branch Rail Trail in Denton, Katy Trail in Dallas and Trinity Trails in Fort Worth.
Note: No adjustments for weather were applied.

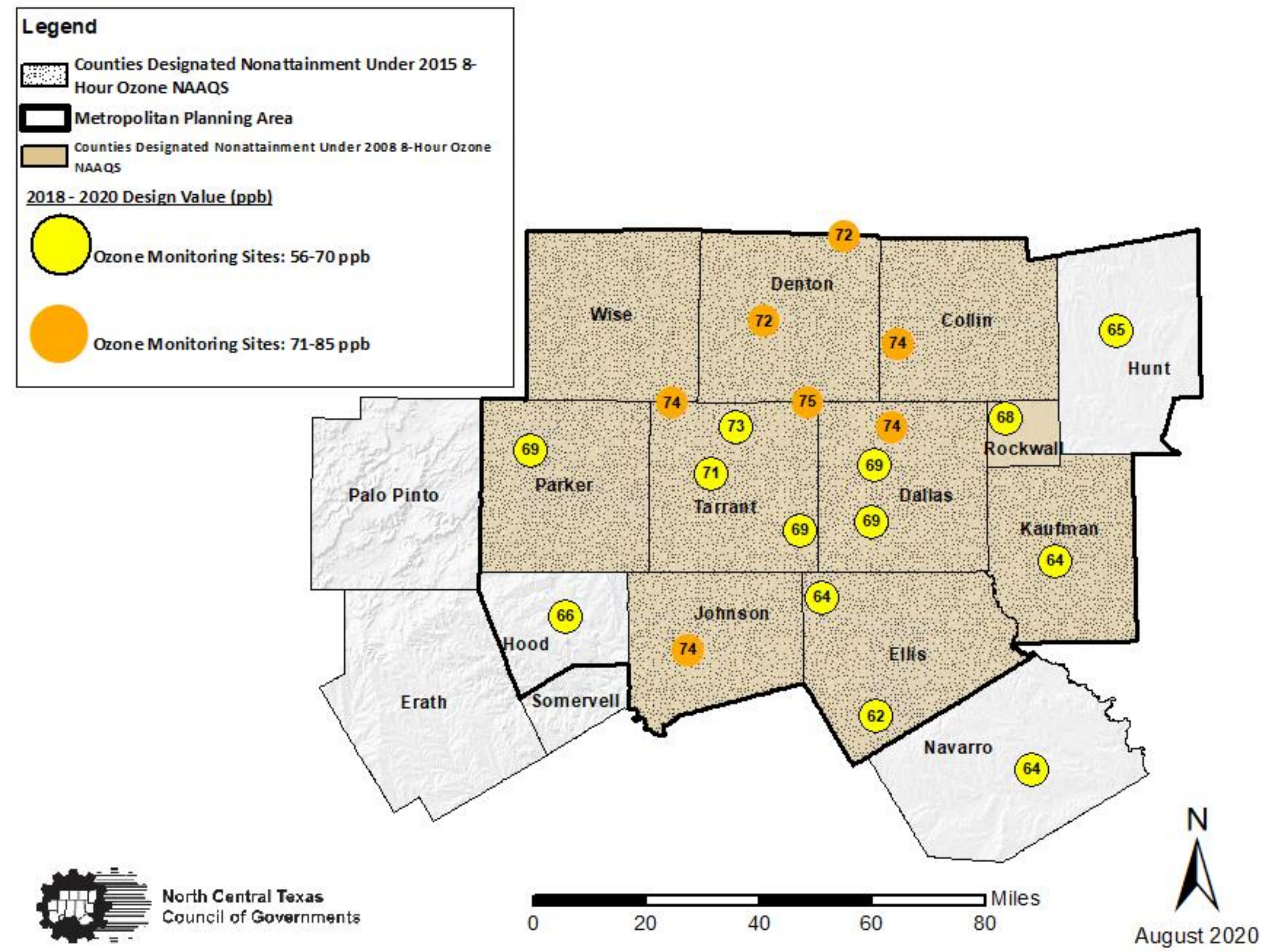
2. AIR QUALITY

Regional Air Quality Impacts During COVID-19

- Emissions from vehicles reduced
- Lowest frequency of high-level, unhealthy, exposure days to ozone
  (prior to exceedances on August 3, 2020)
  - Ozone levels influenced by meteorological conditions: high temperatures, low winds, high UV index, limited rain, and little cloud coverage
- Cleaner air = blue(r) skies
- Leading to a healthier populous (under review)
- Real world analysis on local contributions suggest multi-state SIP’s to reduce background
- How Can We Sustain Impacts? (To be determined)
  Electric and Fuel Cell Vehicles
  Travel Demand Management (Telecommuting)

Real world analysis on local contributions suggest multi-state SIPs to reduce background

DFW OZONE NONATTAINMENT AREA



Colors represent Air Quality Index breakpoints

Attainment Goal - According to the US EPA National Ambient Air Quality Standards, attainment is reached when, at each monitor, the three-year average of the annual fourth-highest daily maximum eight-hour average ozone concentration is less than or equal to 70 parts per billion (ppb).

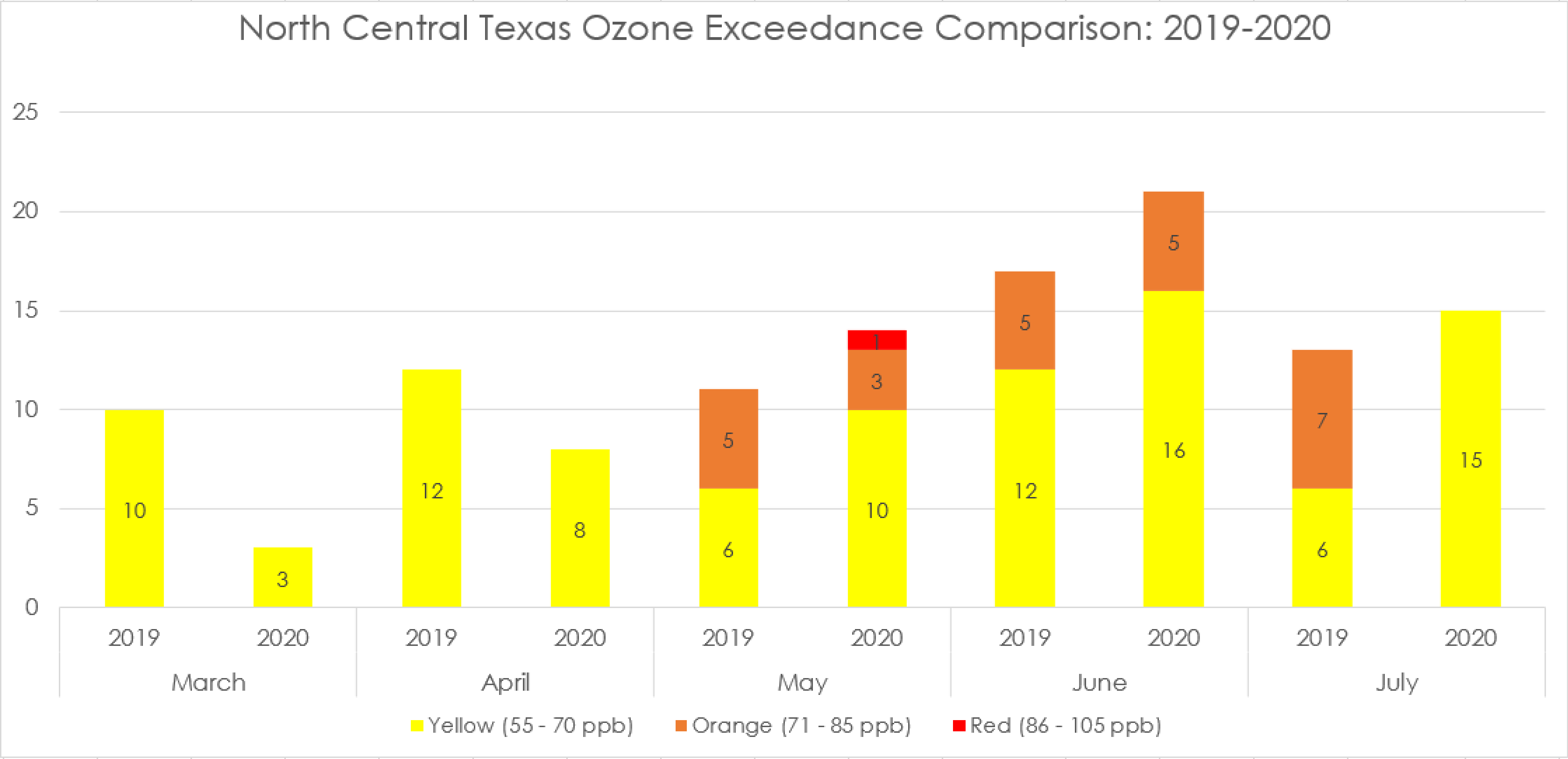
North Central Texas Ozone Comparison

	2017	2018 (3 Year Design Value)	2019 (3 Year Design Value)	2020* (3 Year Design Value)
March	2 yellow days High: 62 at Eagle Mtn Lake	8 yellow days High: 63 at Denton	10 yellow days High: 66 at Clebume	3 yellow days High: 64 at Pilot Point
April	10 yellow days High: 68 at Dallas Hinton	16 yellow days 2 orange days High: 81 at Dallas North High: 81 at Dallas Hinton	12 yellow days High: 69 at Greenville	8 yellow days High: 69 at Rockwall High: 69 at Grapevine
May	15 yellow days 5 orange days High: 80 at Dallas North High: 80 at Dallas Hinton	9 yellow days 6 orange days 2 red days High: 92 at Eagle Mtn Lake	6 yellow days 5 orange days High: 80 at Pilot Point	10 yellow days 3 orange day 1 red day High: 86 at Grapevine Fairway
June	6 yellow days 4 orange days High: 84 at Cleburne Airport	7 yellow days 2 orange days High: 85 at Dallas North	12 yellow days 5 orange days High: 76 at Frisco High: 76 at Arlington Municipal High: 76 at Cleburne Airport	16 yellow days 5 orange days High: 77 at Eagle Mountain Lake
July	14 yellow days 3 orange days High: 81 at Cleburne Airport High: 81 at Granbury	14 yellow days 8 orange days 3 red days High: 92 at Grapevine Fairway	6 yellow days 7 orange days High: 83 at Cleburne Airport	15 yellow days High: 69 at Dallas North
August	11 yellow days 3 orange days High: 83 at Grapevine Fairway	12 yellow days 6 orange days 2 red days High: 91 at Parker County	14 yellow days 5 orange days High: 84 at Keller	10 yellow days 3 orange days 2 red days High: 89 at FT. Worth Northwest

Data Source: TCEQ
Data Analysis: NCTCOG

* as of August 19, 2020. At this time last year (August 19, 2019), there were eight Yellow days and four Orange days.

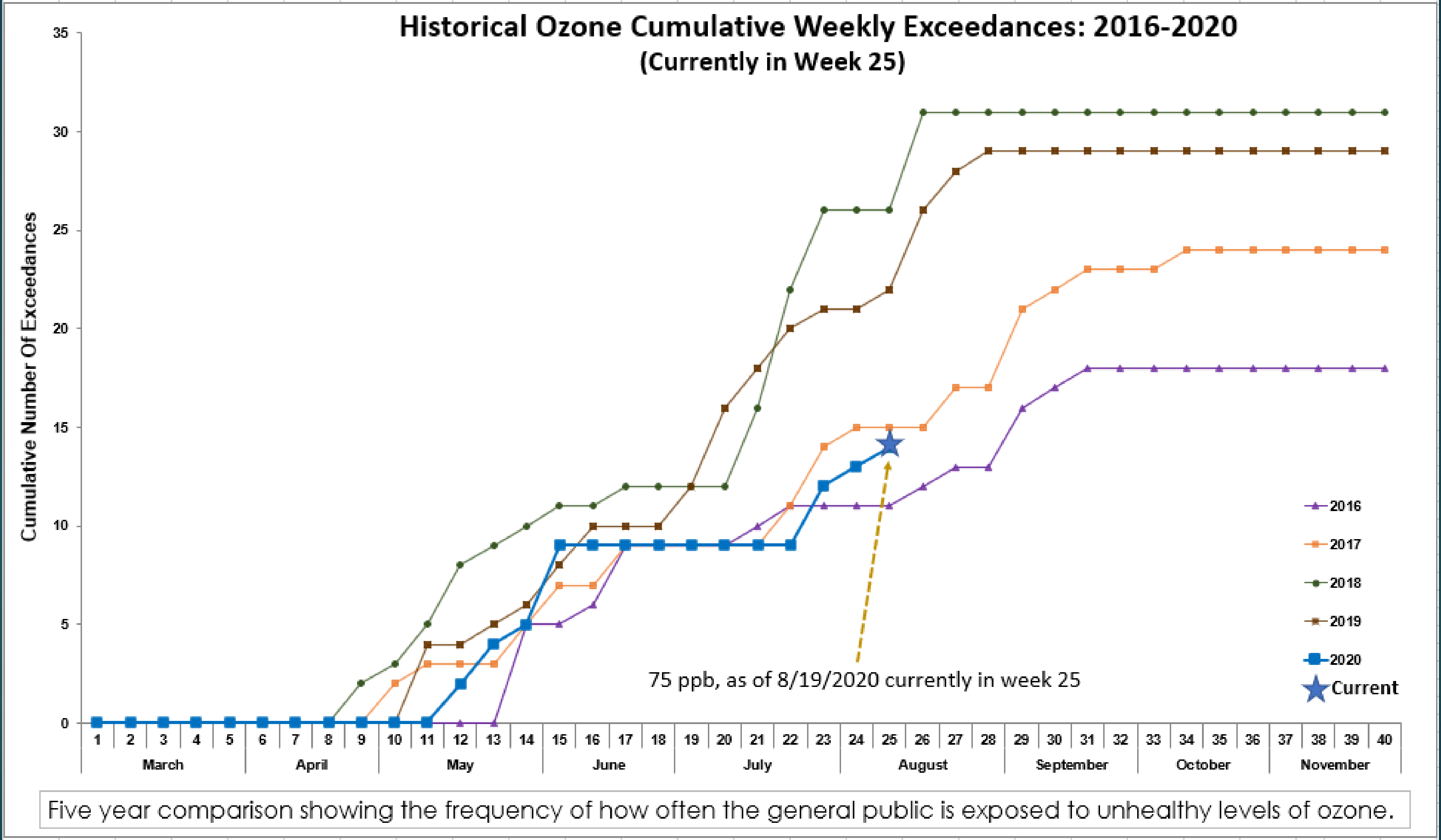
Data Source: Texas Commission on Environmental Quality **Data Analysis: North Central Texas Council of Governments**



Data Source: Texas Commission on Environmental Quality

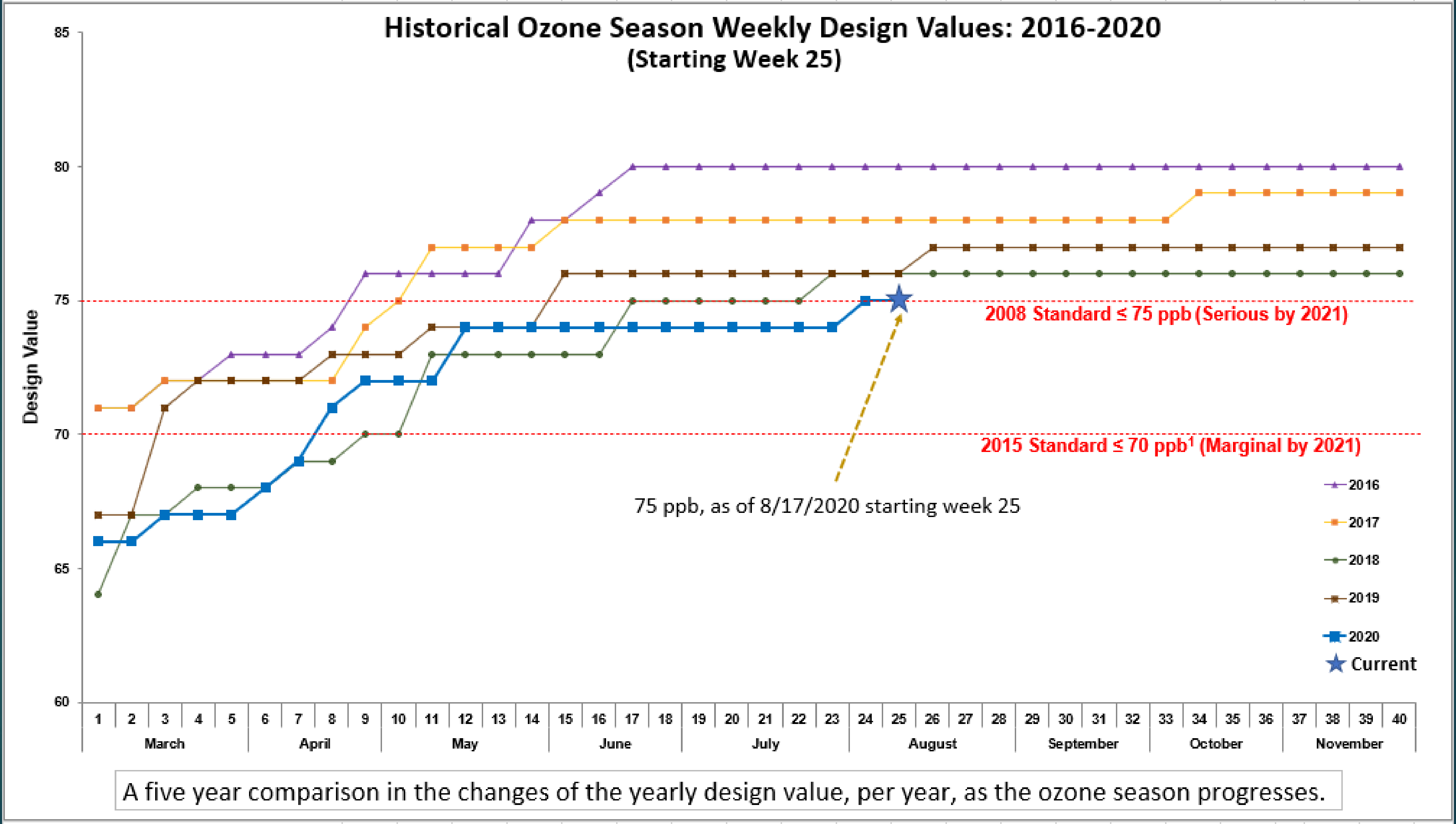
Data Analysis: North Central Texas Council of Governments

Cumulative Ozone Exceedances, 2016-2020



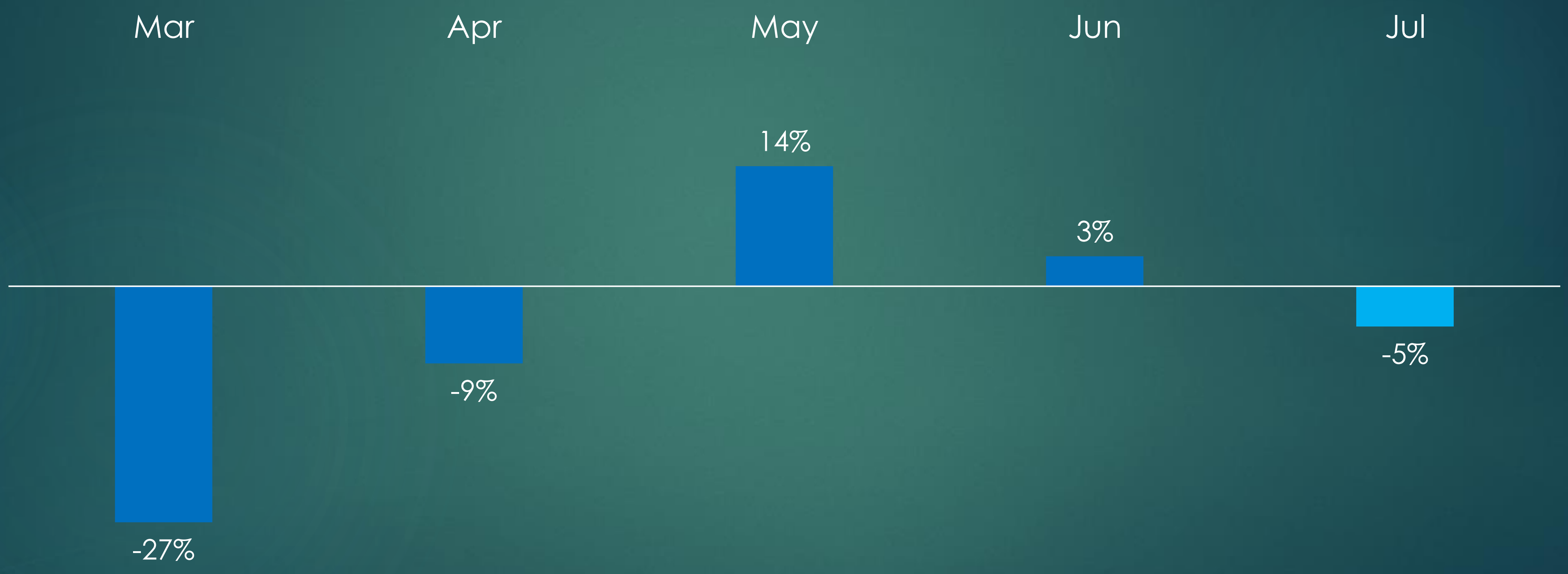
Data Source: Texas Commission on Environmental Quality
Data Analysis: North Central Texas Council of Governments

Weekly Ozone Design Values, 2016-2020



Data Source: Texas Commission on Environmental Quality
Data Analysis: North Central Texas Council of Governments

Percent Change in Average Regional Ozone* Emissions: 2019 vs 2020



*ozone levels are influenced by meteorological conditions: high temperatures, low winds, high UV index, limited rain, and little cloud coverage.

Data Source: Texas Commission on Environmental Quality **Data Analysis: North Central Texas Council of Governments**

FOR MORE INFORMATION, PLEASE CONTACT:

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