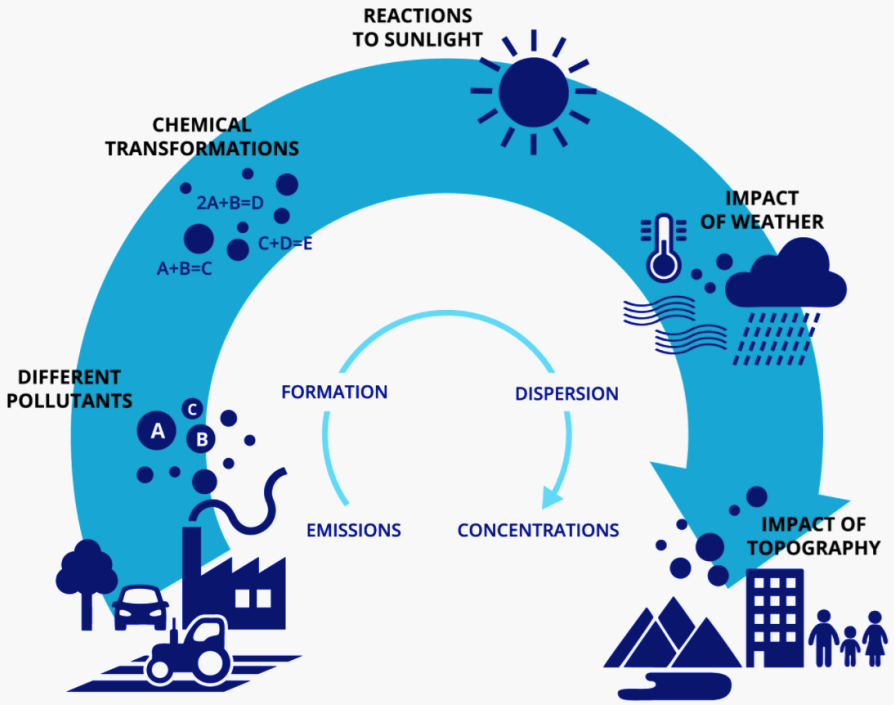
2026 TWG Quarterly Meeting

Quantify the Real Impact of Transportation Activity on Regional Ozone



Sponsored by the

Texas Department of Transportation

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Project Overview

Project Overview

- Background

TxDOT, TCEQ, and MPOs rely on modeling to comply with air quality regulations

Currently accepted assumption:

Reduced emission from traffic automatically means improved air quality

Air quality data observed during the pandemic showed mixed behavior

Pandemic-induced changes in transportation activities created an opportunity to examine the details of the impact of traffic-related emissions on air quality

Project Overview

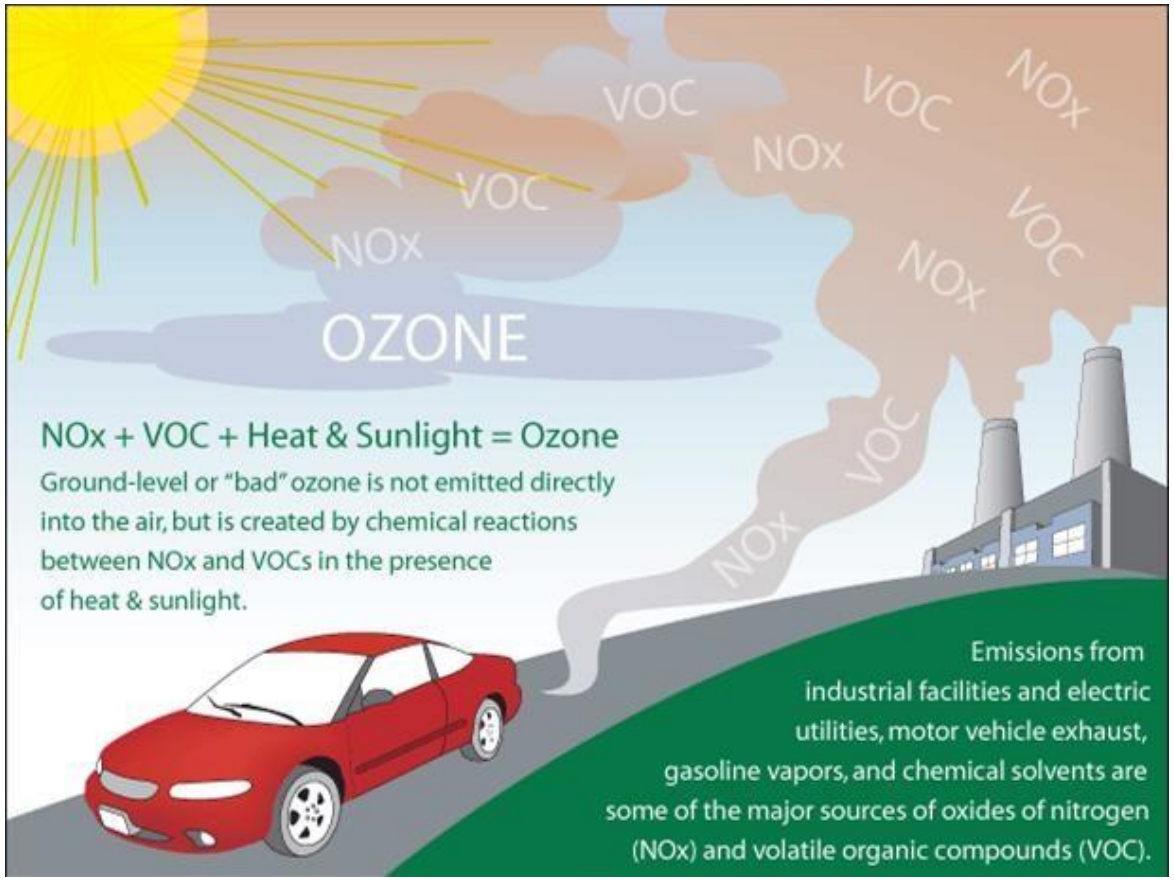
- Quantify the Real Impact of Transportation Activity on Regional Ozone and Near-Road PM Concentrations

  - Examine the **extent of transportation's impacts on air quality** through an analysis of **before-** and **during-pandemic** traffic activity and air quality monitoring data

  - **Evaluate the performance** of
    - **Photochemical modeling** in capturing the changes in **regional O_3** in response to changes in traffic activities
    - **Air dispersion modeling** in capturing the changes of **near-road $PM_{2.5}$** concentrations in the near-road environment resulting from traffic activity variations

Why ground-level O_3?

- Ground-level O_3 forming process



- O_3 is the main ingredient of Smog

- PBS documentary film "Clearing the Air: the War on Smog" Link

Source: EPA (https://www.epa.gov/ground-level-ozone-pollution/ground-level-ozone-basics#wwh)

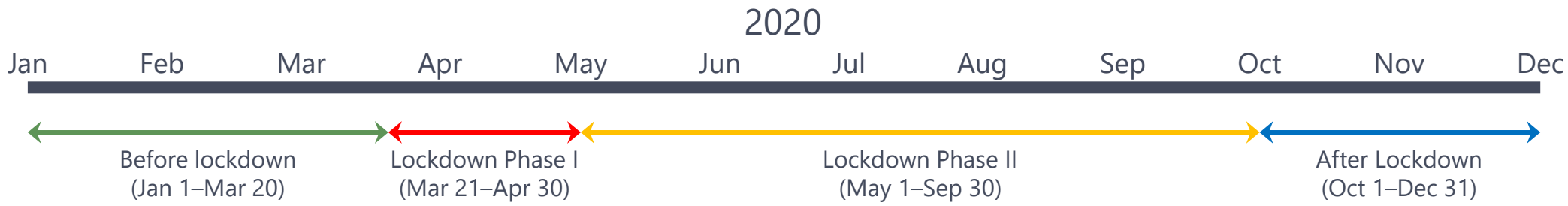
Transportation Activity and Emission Modeling

Transportation Activity and Emission Modeling
- Assumption

- Core assumptions of the study
  - COVID-19 **changes individual travel behavior**
  - COVID-19 **changes population** in a region
  - Use **different factors (variables)** for **COVID** and **No COVID scenarios** if data can support the assumption. In other words, **use the same factors** for COVID and No COVID **if there is no evidence/data** to show the differences.

Transportation Activity and Emission Modeling
- Scope of the Study

- Temporal scope
  - Split year 2020 into four, based on business restriction executive order due to COVID-19

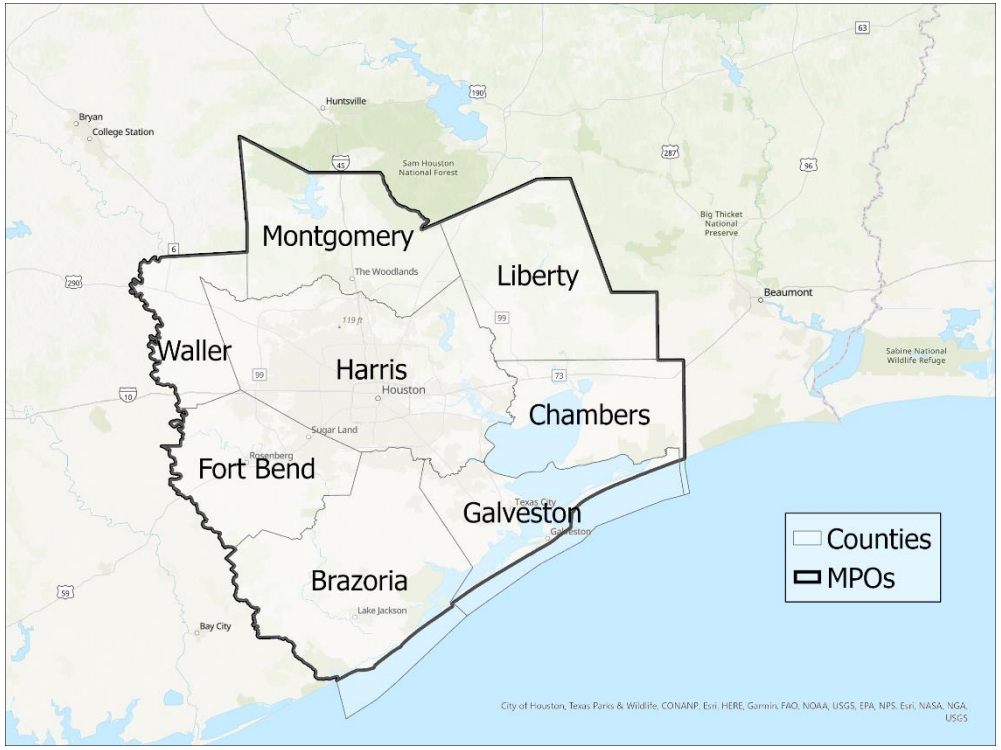


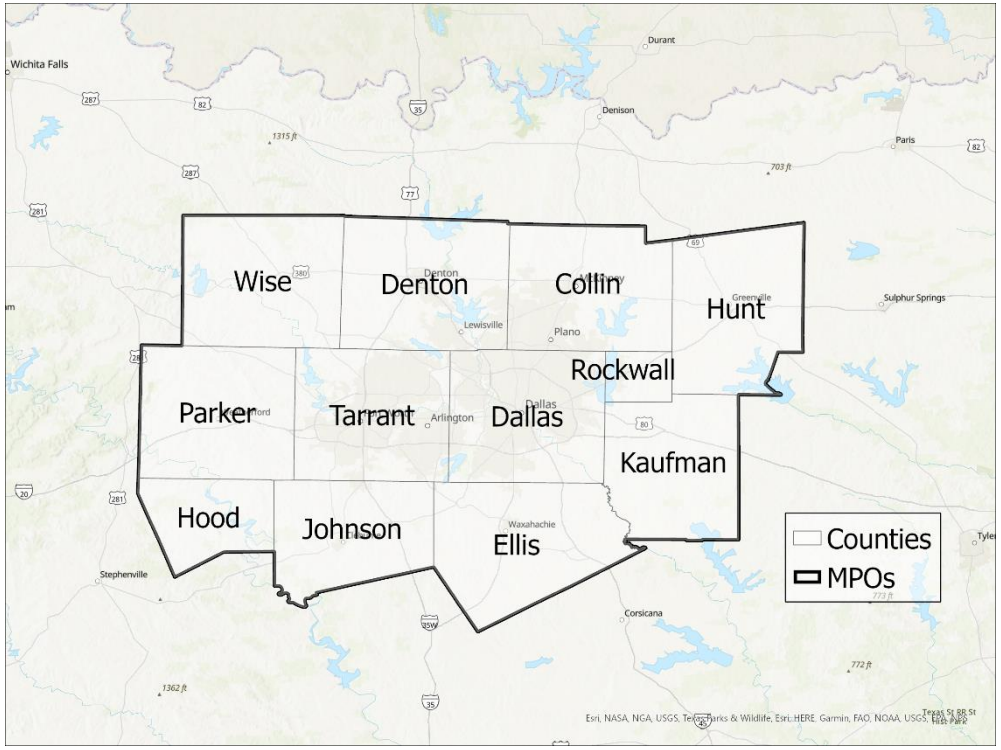
- Before lockdown (P1) : Before significant COVID-19 impact, no stay-at-home order
- Lockdown Phase I (P2) : Execute stay-at-home order
- Lockdown Phase II (P3) : Open business at 25% capacity → 75% capacity
- After lockdown (P4) : End of O_3 season

Transportation Activity and Emission Modeling

- Scope of the Study

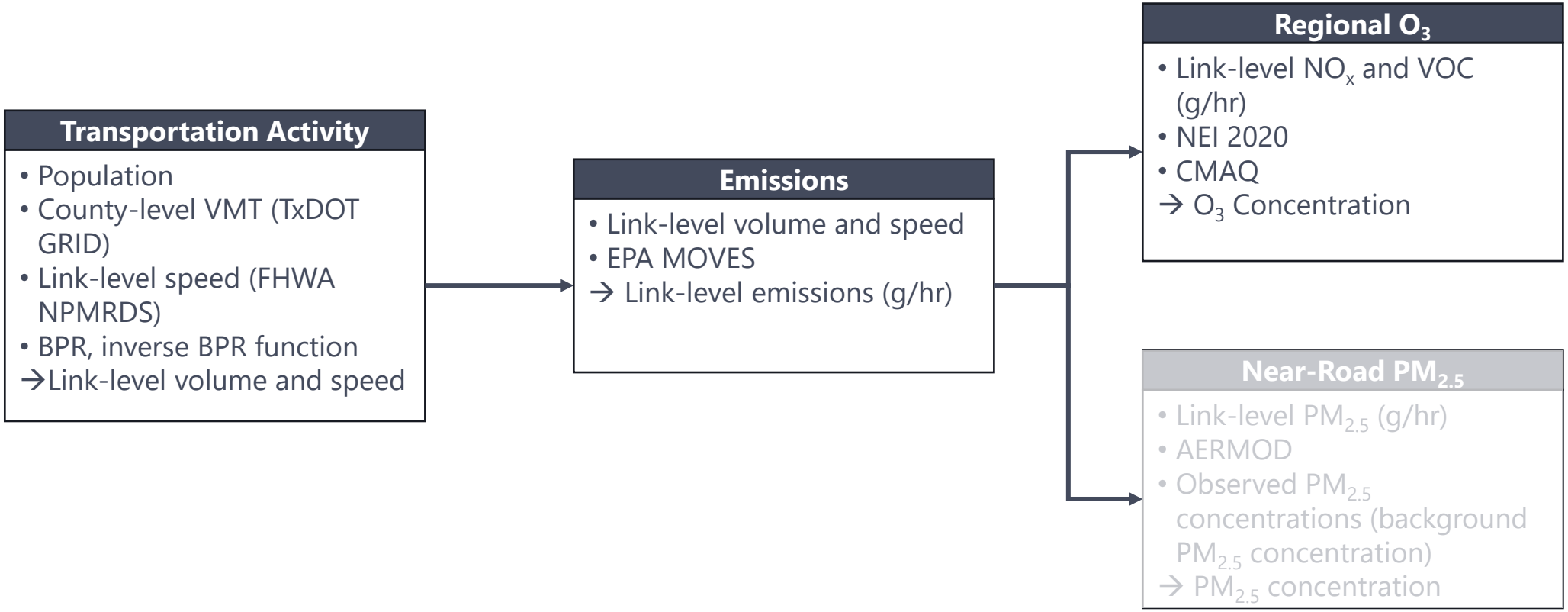
- Spatial scope for regional O_3
  - Houston (HGB) and Dallas Fort Worth (DFW)—two O_3 nonattainment areas in Texas





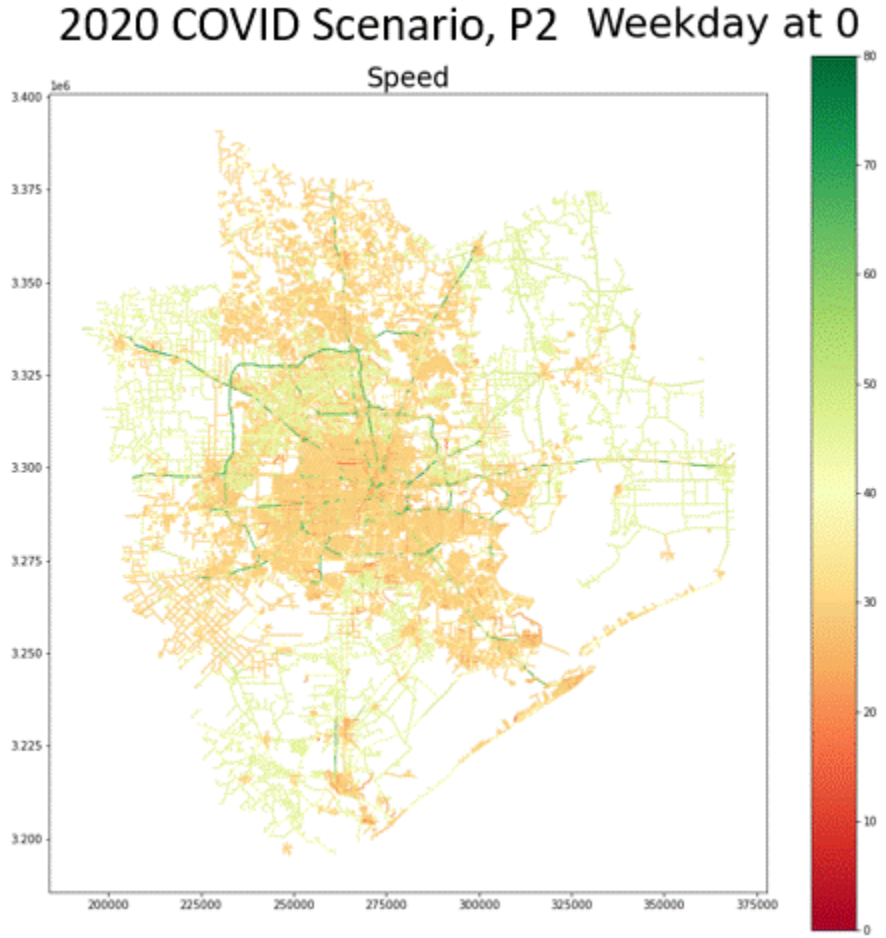
Transportation Activity and Emission Modeling
- Modeling Chain in this study

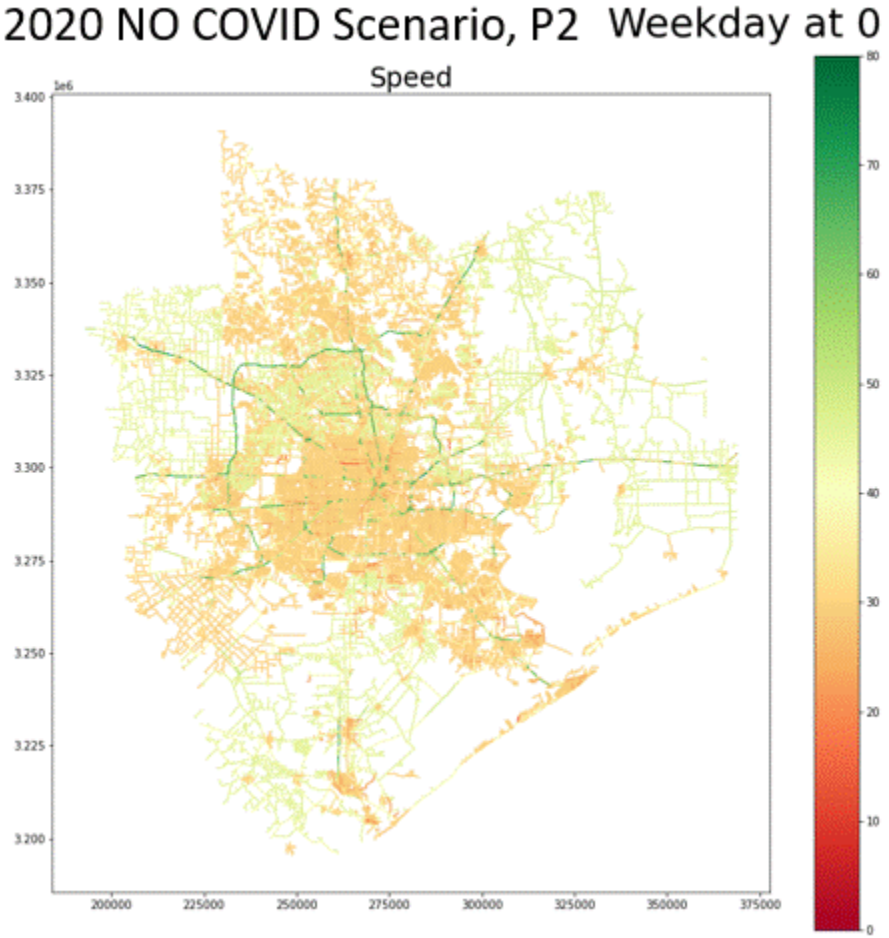
- Emission concentration modeling chain (full modeling chain)



Transportation Activity and Emission Modeling
- Estimating Transportation Activities

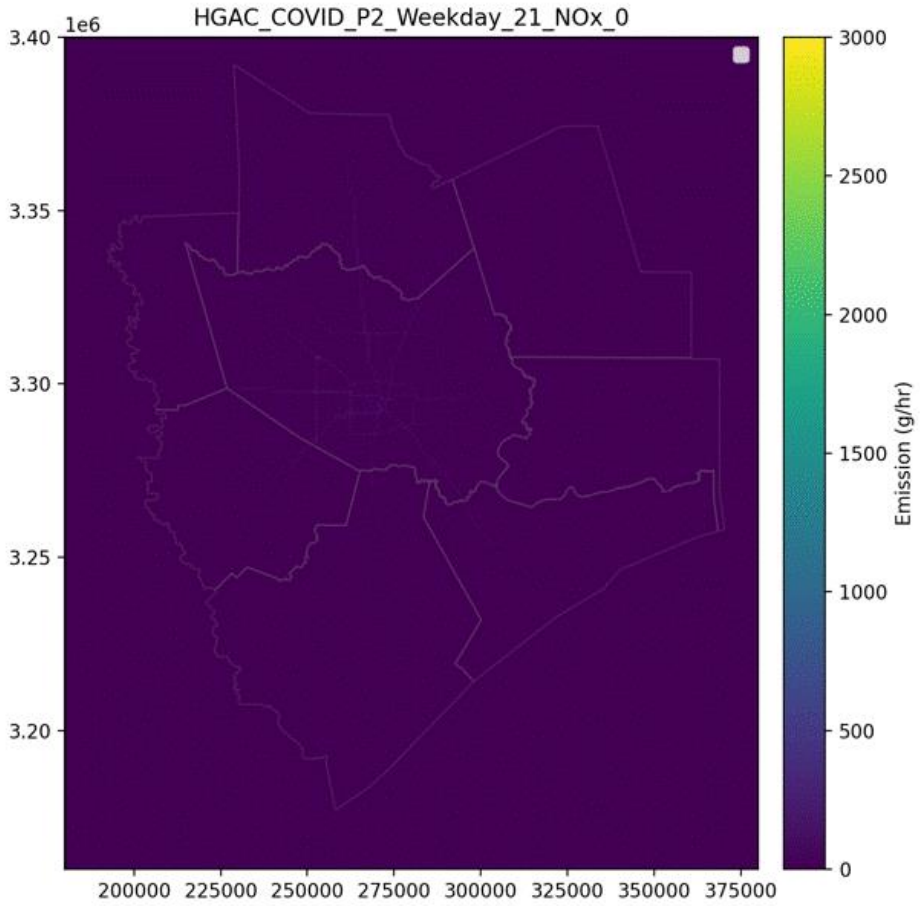
- Transportation activities output
  - Speed comparison: COVID vs. No COVID, lockdown Phase I (P2)

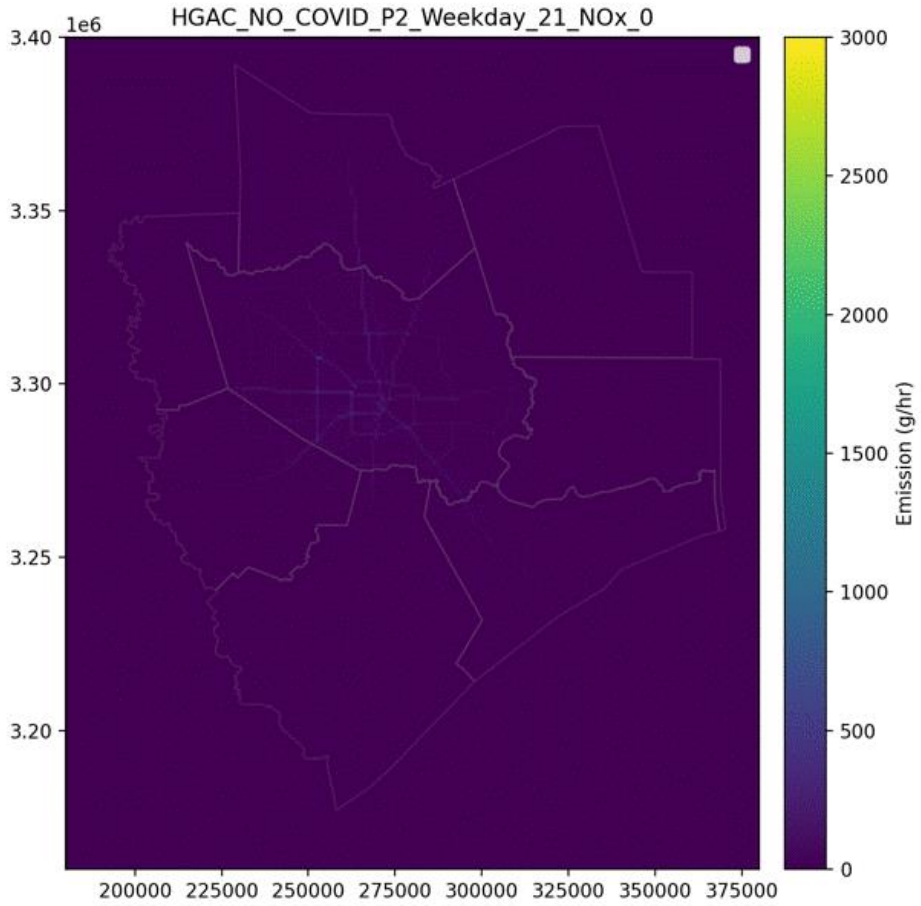




Transportation Activity and Emission Modeling
- Estimating Emissions

- Emission Estimation (MOVES3)
  - NO_x (g/hr) comparison: COVID vs. No COVID, lockdown Phase I (P2)



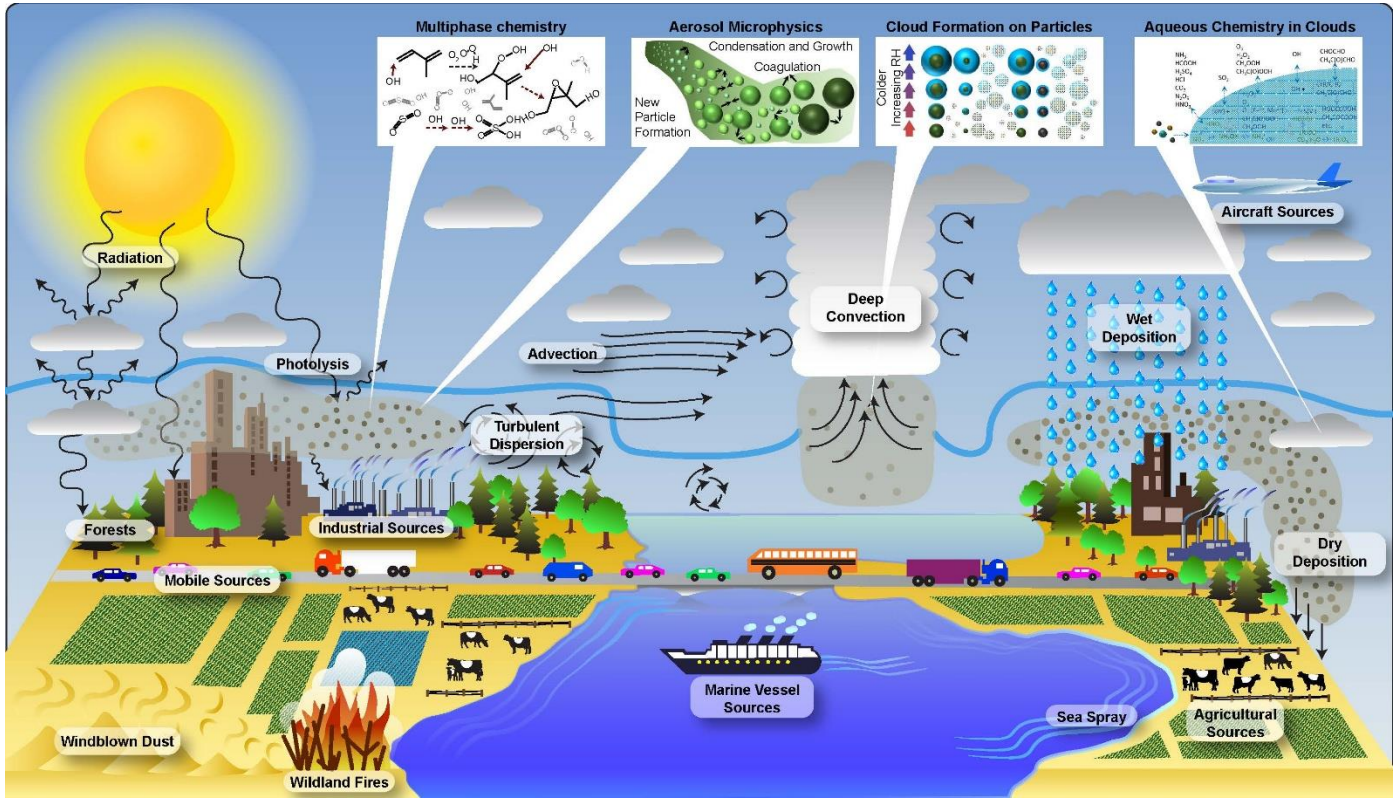


Regional Photochemical O_3 Modeling

Regional Photochemical O_3 Modeling

- Atmospheric Models Are Essential Tools

- Numerical modeling is required because:
  - Pollutants of concern are not always directly emitted but often created in the atmosphere
  - Atmospheric chemistry is complex and nonlinear
- Atmospheric models allow us to:
  - Simulate the complexity of atmospheric chemistry
  - Understand future air quality
  - Fill in gaps spatially where monitors do not exist
  - Formulate and test potential control strategies



Source: U.S. EPA

Regional Photochemical O_3 Modeling

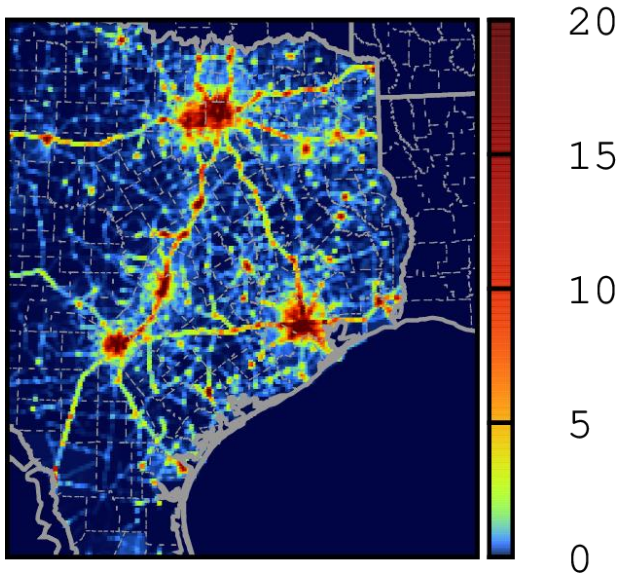
- Community Multiscale Air Quality (CMAQ) Modeling System

TAMU High Performance Research Computing

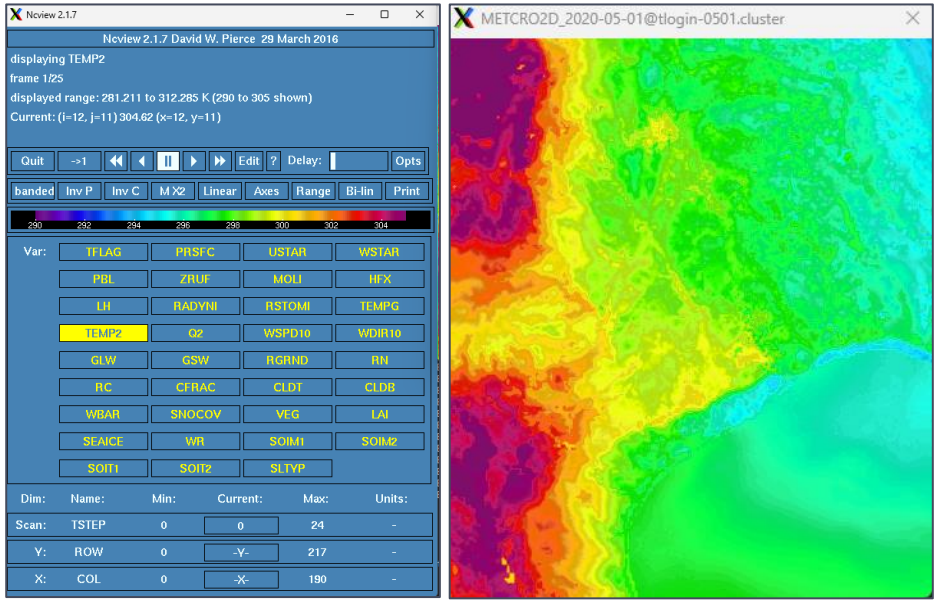
CMAQ predicts hourly concentration and deposition values for a large number of chemical species for each location in the modeled domain

Key Inputs

- 2020 National Emission Inventory (NEI)
- Weather Research and Forecasting (WRF)
- Estimated on-road emission (previous step)



NEI NO_x Emission (Ton)



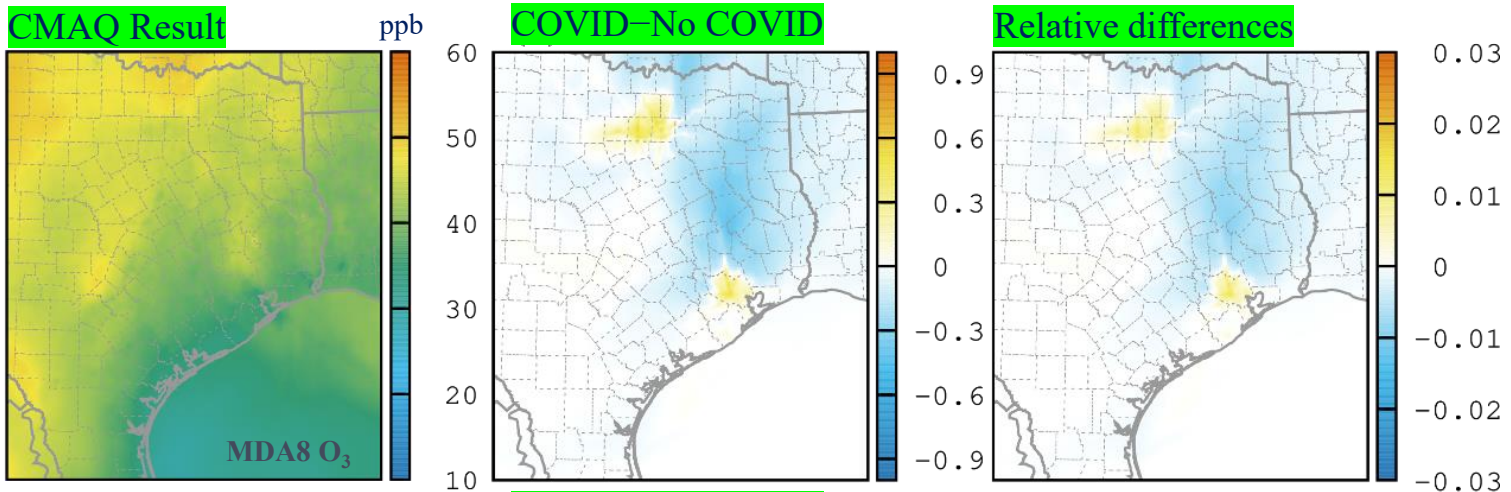
WRF Predicted 2m Temperature (K)

Regional Photochemical O_3 Modeling

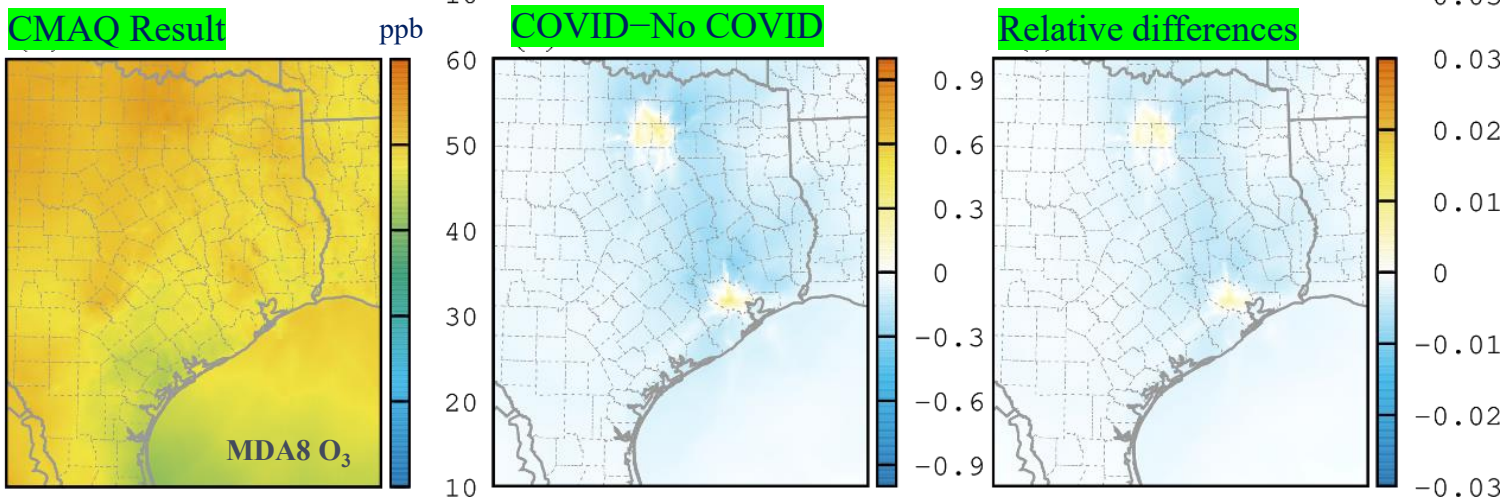
- Model Results

- MDA8 O_3 differences (COVID v. No COVID) in P2

Mar 15 – Mar 31



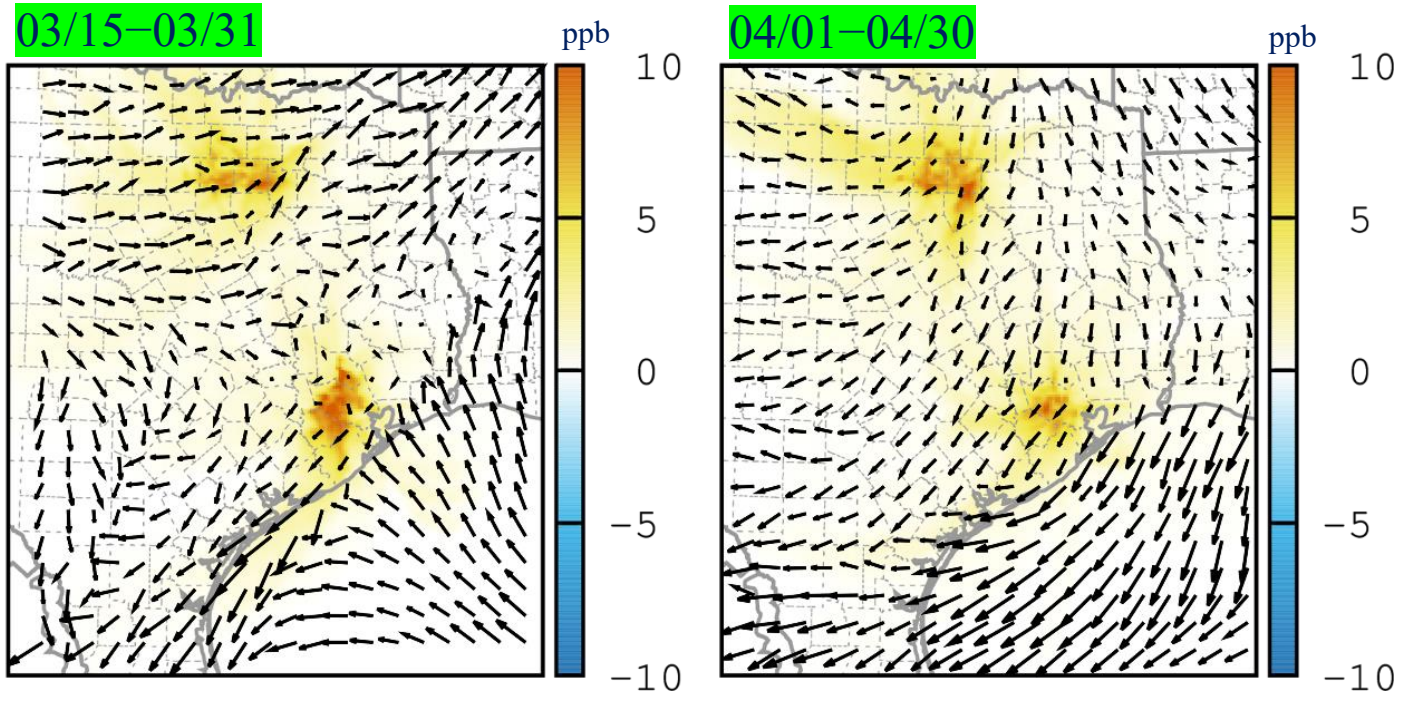
Apr 1 – Apr 30

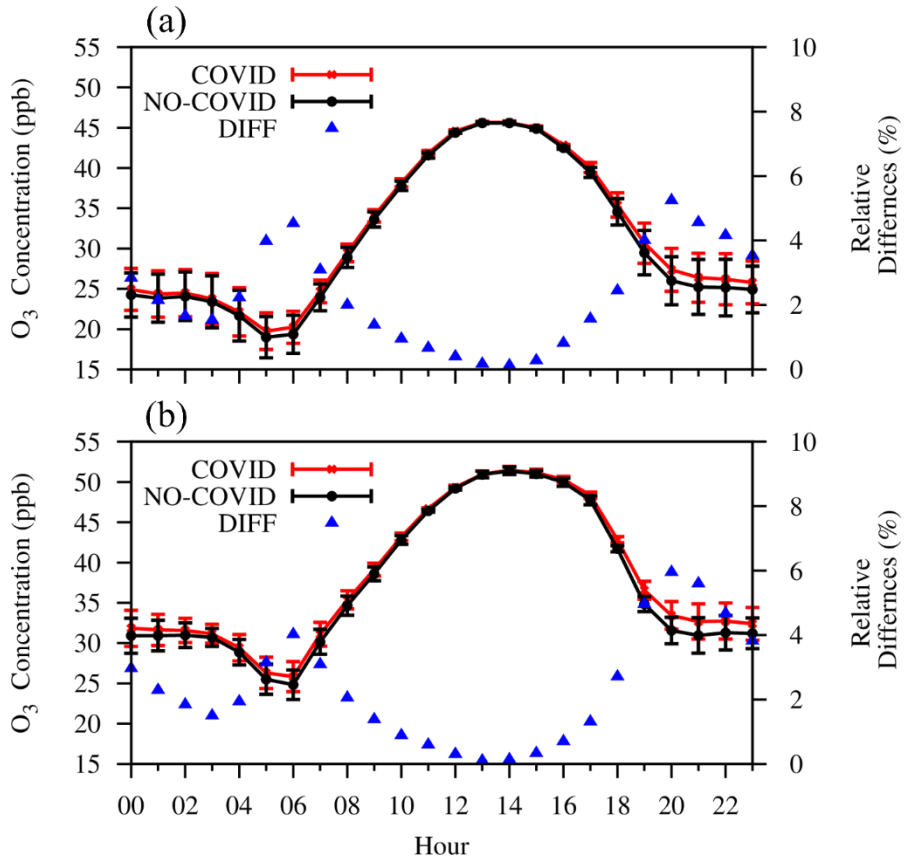


Regional Photochemical O_3 Modeling

- Model Results

- Hourly O_3 differences (COVID v. No COVID) in P2
  - Significant O_3 reduction during the night/early morning (see ▲)

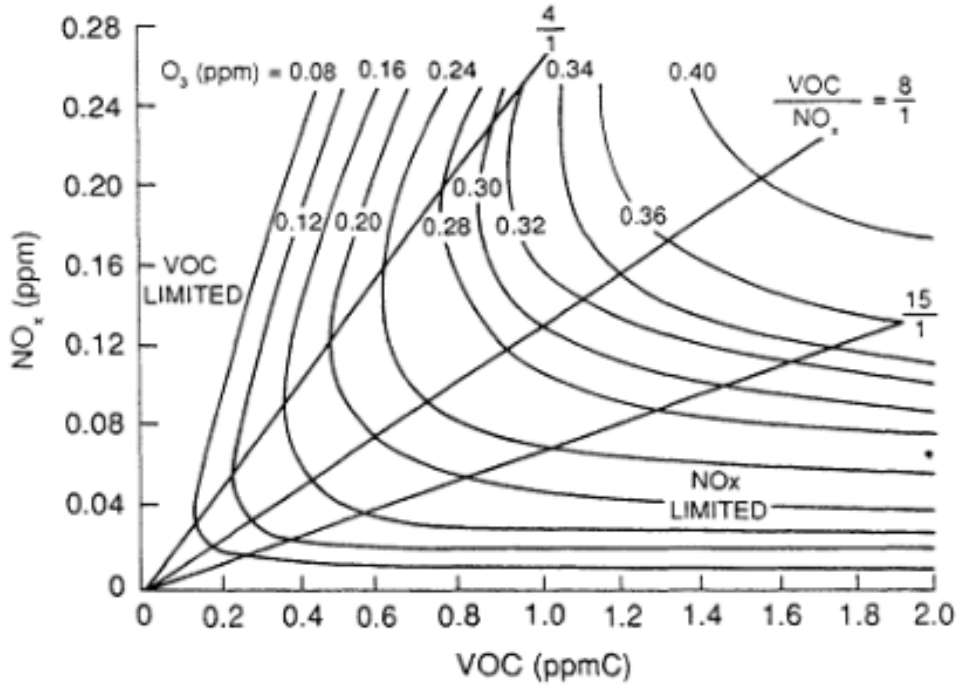




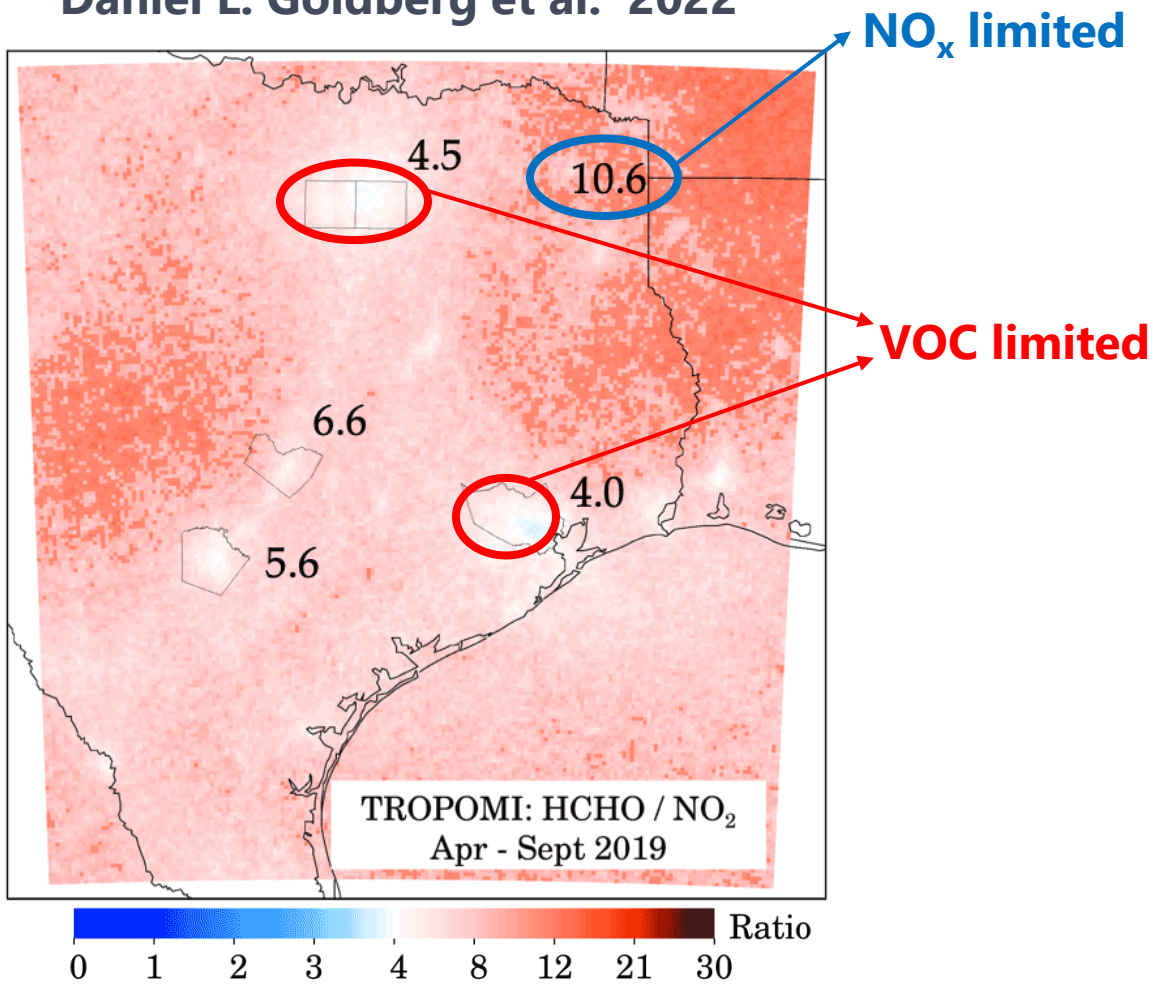
Regional Photochemical O_3 Modeling

- Ozone Formation

Finlayson-Pitts and Pitts et al. 1993



Daniel L. Goldberg et al. 2022



NO_X limited = with relatively low NO_X and high VOCs

VOC limited = with relatively high NO_X and low VOCs

Regional Photochemical O_3 Modeling
- Ozone Formation

- Urban areas in Texas are **VOC-limited** regime (more NOx, less VOC)
  - More **NOx cannot generate** more **O_3**
  - More **VOC can generate** more **O_3**

- O_3 titration can reduce O_3 during the nighttime
  - O_3 is generated by NOx, VOC, Heat, and sunlight (balance matters)
  - During the nighttime, when the heat and sunlight are limited, O_3 is depleted through its reaction with NO, leading to the removal of O_3

$$O_3 + NO \rightarrow NO_2 + O_2$$

  - Since our target areas are VOC-limited (plenty of NOx, including NO), O_3 was reduced (especially when there is no heat and sun) due to the O_3 titration

Conclusions

Conclusions

- Two major factors that affect transportation activity changes due to COVID-19
  - Individual travel behavior: people travel less (lockdown, WFH, etc.)
  - Population change: migration from other states, moving out to the suburbs

- During COVID, Urban areas experienced less than a 1.5 ppb increase in maximum daily 8-hour average (MDA8) O_3 due to the reduced O_3 titration effect (VOC-limited regime)

- Suburban/rural areas had a slight decrease in MDA8 O_3 (NOx-limited regime) in the COVID scenario compared to the No COVID scenario

Takeaways – What does the result mean?

- Texas currently has several metropolitan areas that are regulated under the Clean Air Act, and the state is generally interested in **reducing the impacts of transportation on the environment**

- Modeling transportation activities, emissions, and air quality (i.e., pollutant concentrations) is required for regulatory decision making → **Full modeling chain (transportation → emission → concentration) is needed**

- The results of this study suggest that established modeling methodologies are useful tools for predicting and **understanding the contribution of historical transportation activities to air quality**

Thanks

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