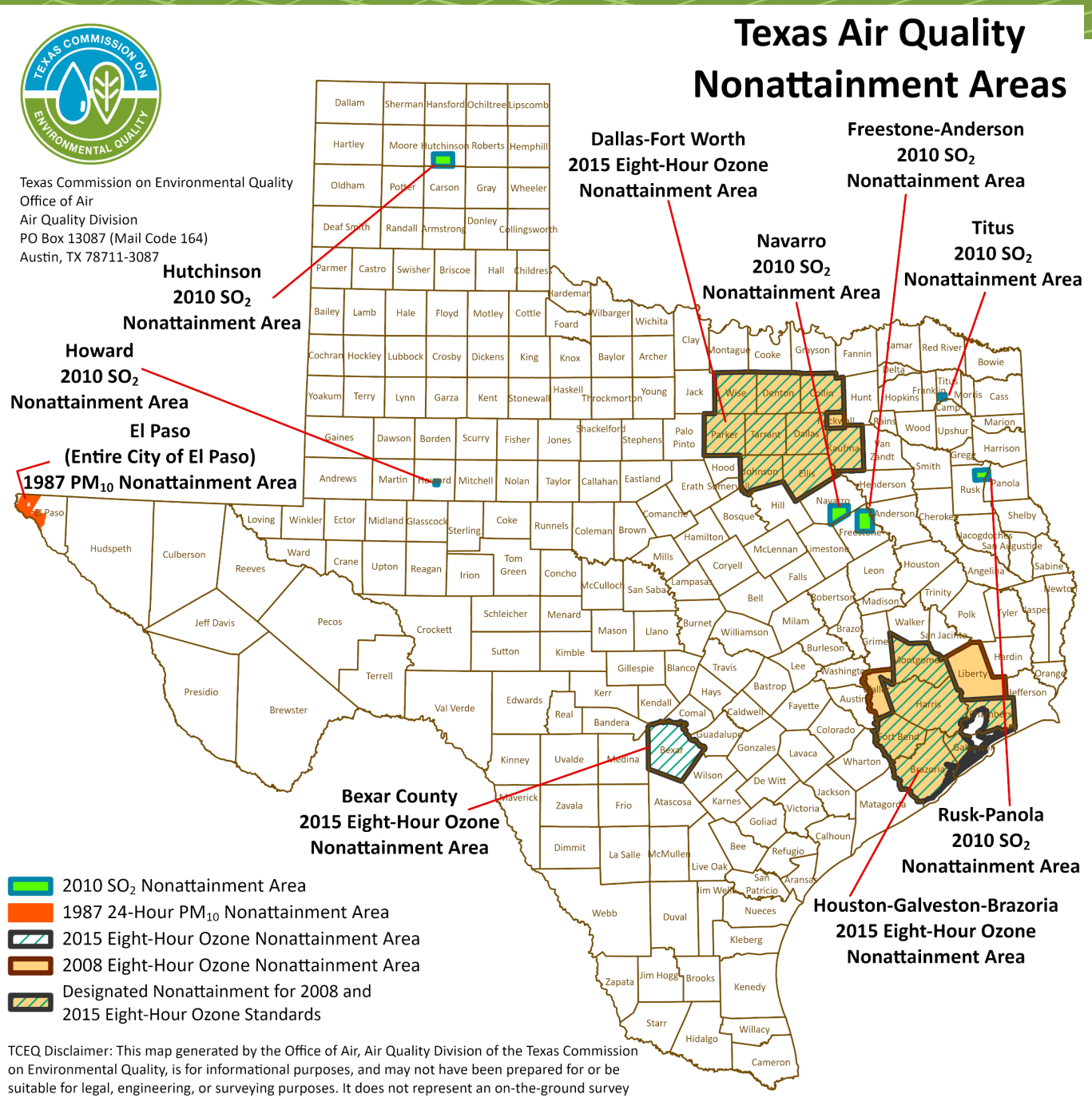
Texas Air Quality Research

Beata Czader, PhD
Air Quality Division
Environmental Trade Fair 2025

Overview

- Air Quality Planning Challenges
- Support for Texas Air Quality Research
- Research Results in Regulatory Work
- Research Related to Texas Air Quality
  - Chemical Mechanisms
  - Meteorology

Air Quality Planning Challenges



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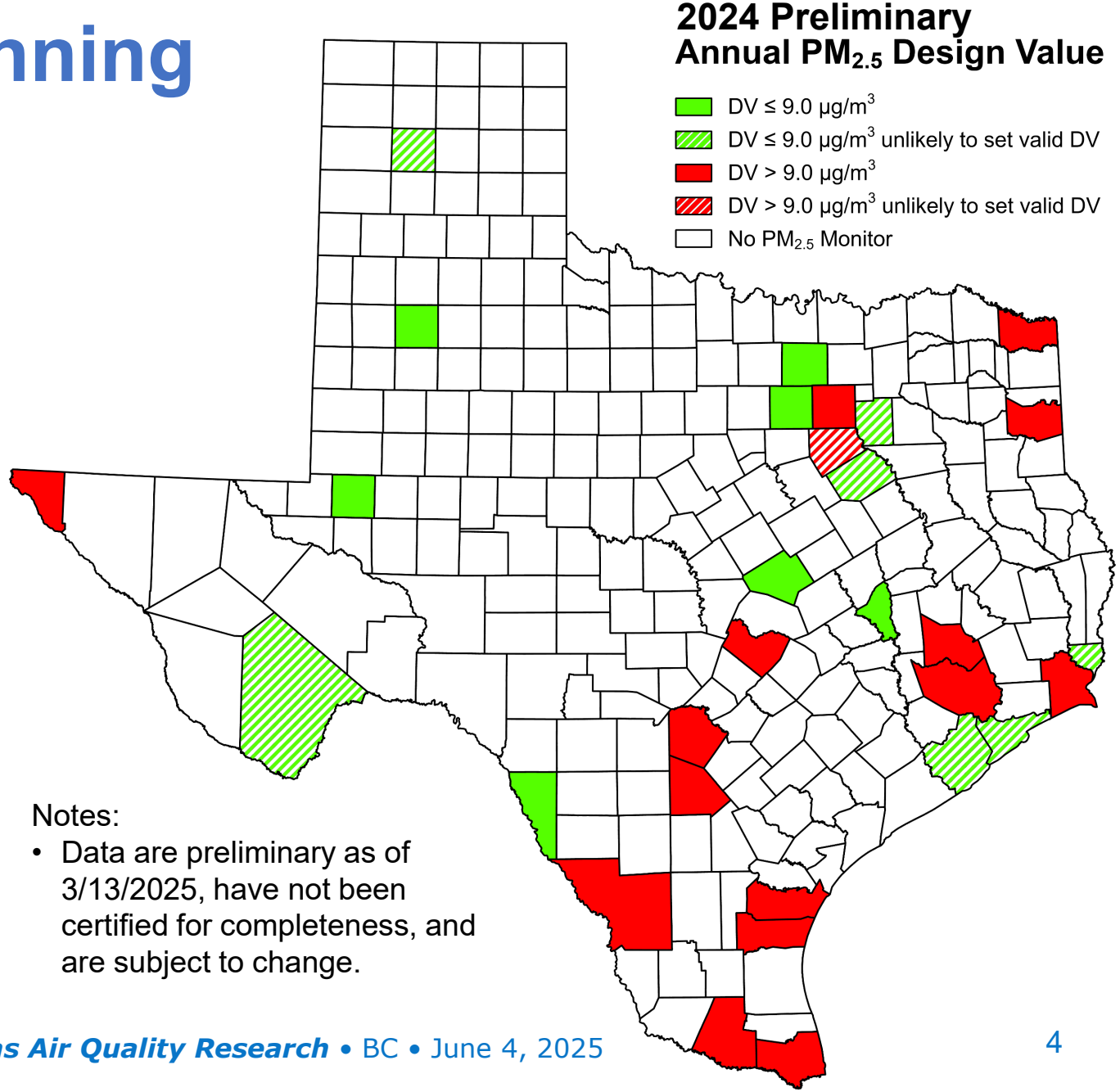
Made by: Laramie Mahan March 6, 2025

Future Air Quality Planning Challenges

- 2024 fine particulate matter ($PM_{2.5}$) National Ambient Air Quality Standard (NAAQS) revision
  - Revised Primary Annual Standard: 9.0 µg/m^3
- Final designations expected in 2026



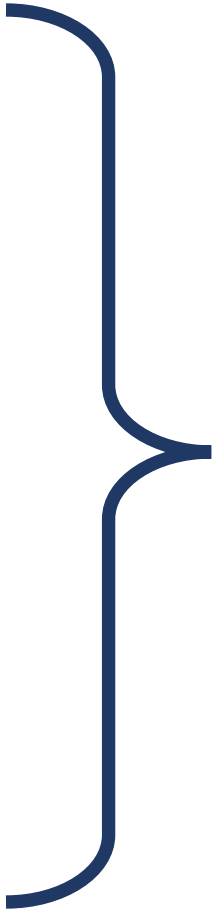
Notes:
- Data are preliminary as of 3/13/2025, have not been certified for completeness, and are subject to change.

Air Quality Research Support in Texas

- Air Quality Research Program (AQRP): Supports research in the areas of emission inventories, atmospheric chemistry, meteorology, and air quality.
  - https://aqrp.ceer.utexas.edu/
- TCEQ-funded air quality research: Applied research projects for TCEQ requirements and goals.
  - https://www.tceq.texas.gov/airquality/airmod/project
- Rider 7: TCEQ-funded research to understand ozone and particulate matter in certain attainment counties.

How Are Research Results Used?

- Improve air quality modeling
  - Updates to chemical mechanisms for ozone and particulate matter
- Improve meteorological modeling
  - Use observed data to constrain modeled parameters
- Develop tools for modeling and analysis
- Measurement campaigns provide data
  - Model performance evaluations
- Analyze high pollution events and trends



Support State Implementation Plan Development

Sources of Ozone and Particulate Matter Pollution

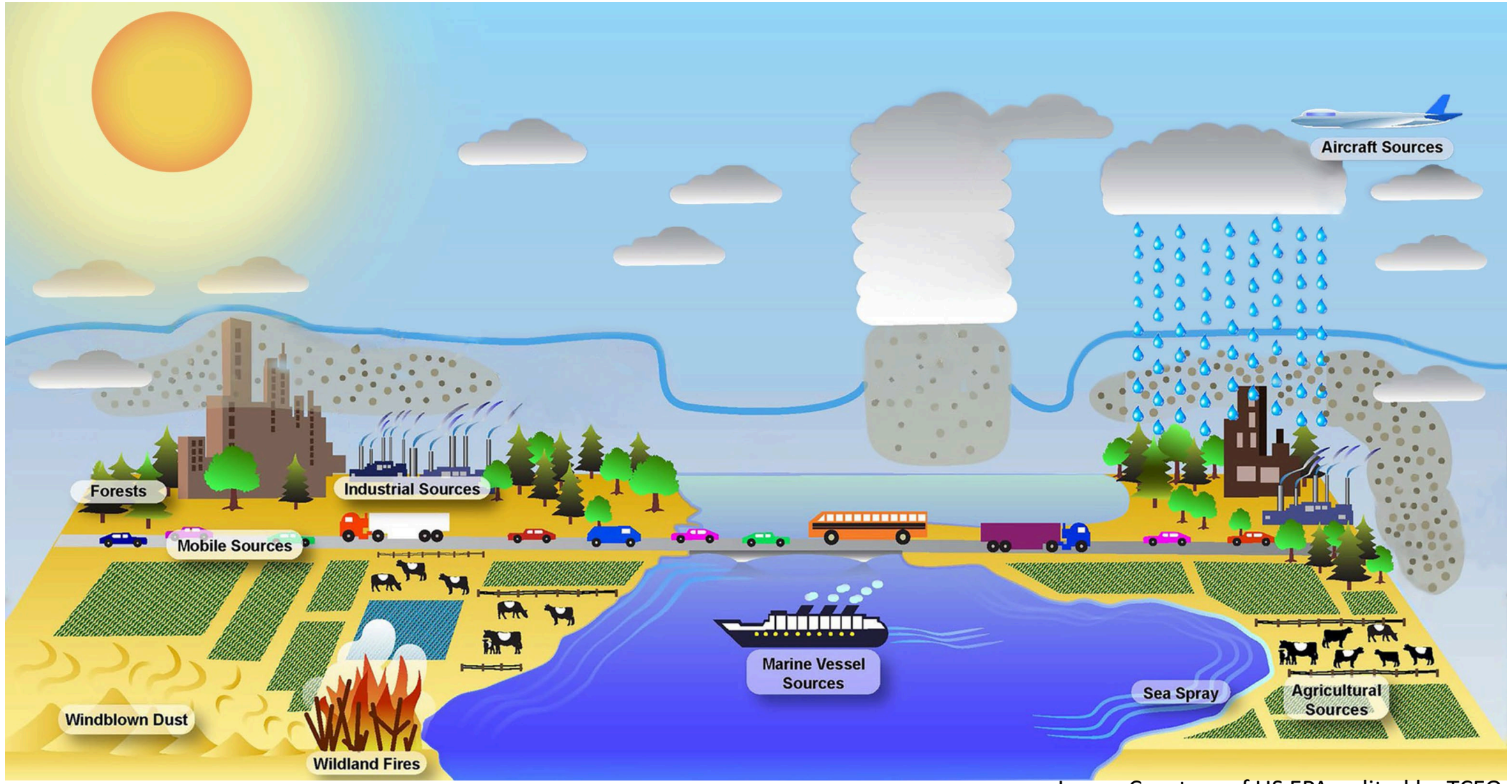


Image Courtesy of US EPA; edited by TCEQ

Ozone Formation

Ozone is formed by chemical reactions in the presence of sunlight.

“Good” ozone

“Bad” ozone

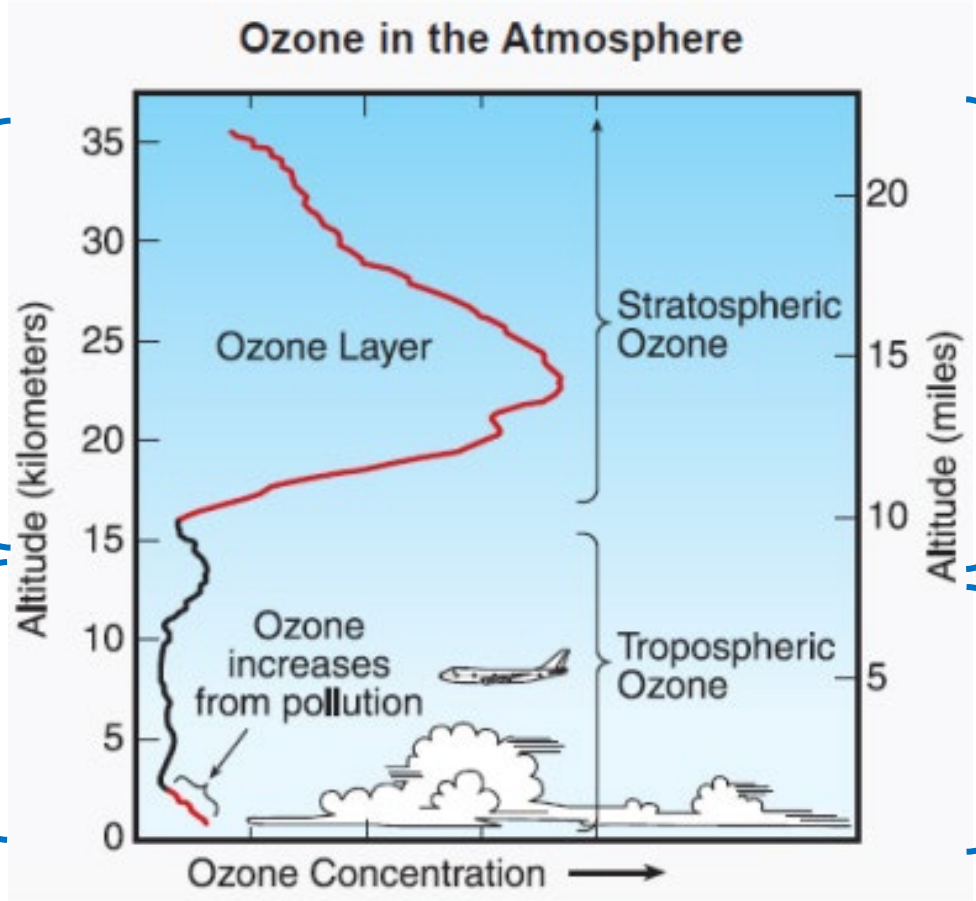


Image Courtesy of World Meteorological Organization

Oxygen and ozone in a steady state

Ozone formation governed by emissions

- **V**olatile **O**rganic **C**ompounds – VOC
- **N**itrogen **O**xides – NOx

Particulate Matter (PM) Defined

- $PM_{2.5}$ or fine PM: particles with diameters of 2.5 micrometers and smaller
- PM_{10} or coarse PM: particles with diameters smaller than 10 micrometers
- PM is directly emitted AND formed in the air
- PM formation and growth
  - Chemical transformations
  - Gas-to-particle conversion
  - Coagulation and condensation

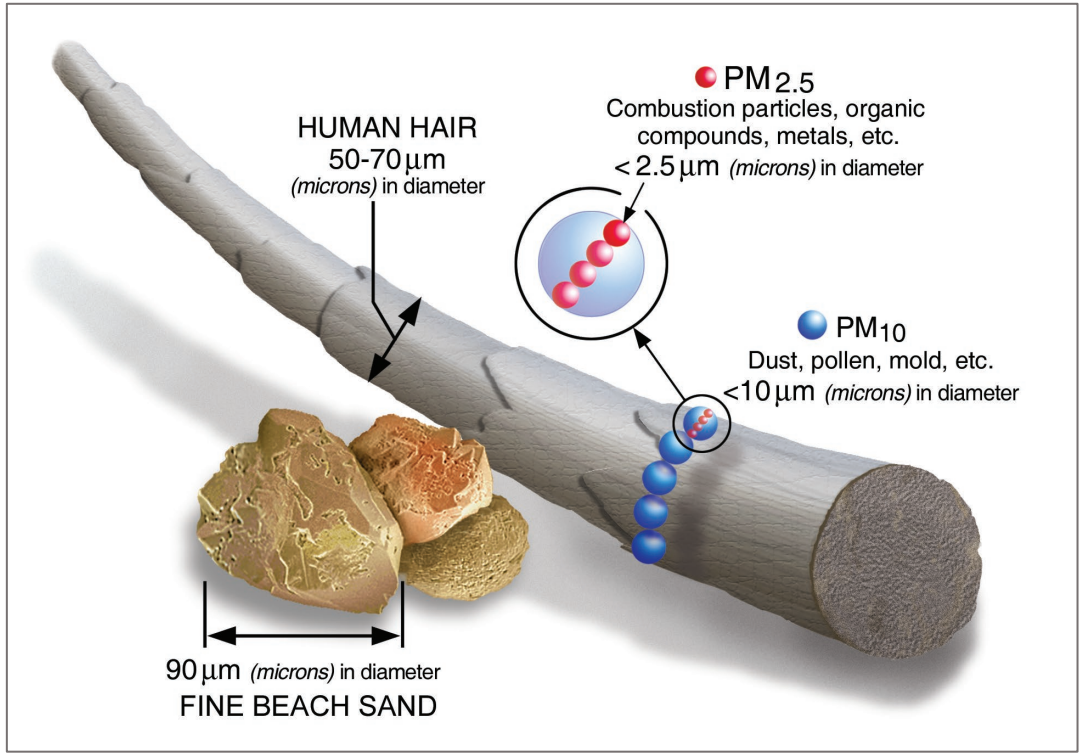
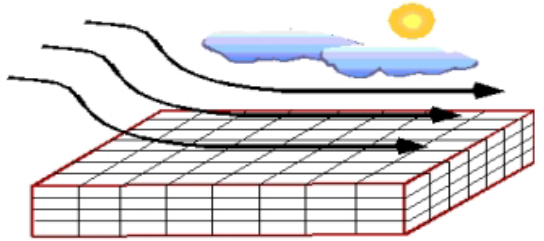


Image Courtesy of US EPA

Ozone and Particulate Matter Modeling

Real World Situation



Computer Grid Simulation

Weather
- Wind
- Temperature
- Pressure
- Clouds
- Mixing Height
- Rain

Emissions
- Industrial
- Transportation
- Biogenic
- Fires

Air Quality Model
- Advection
- Diffusion
- Deposition
- Chemistry

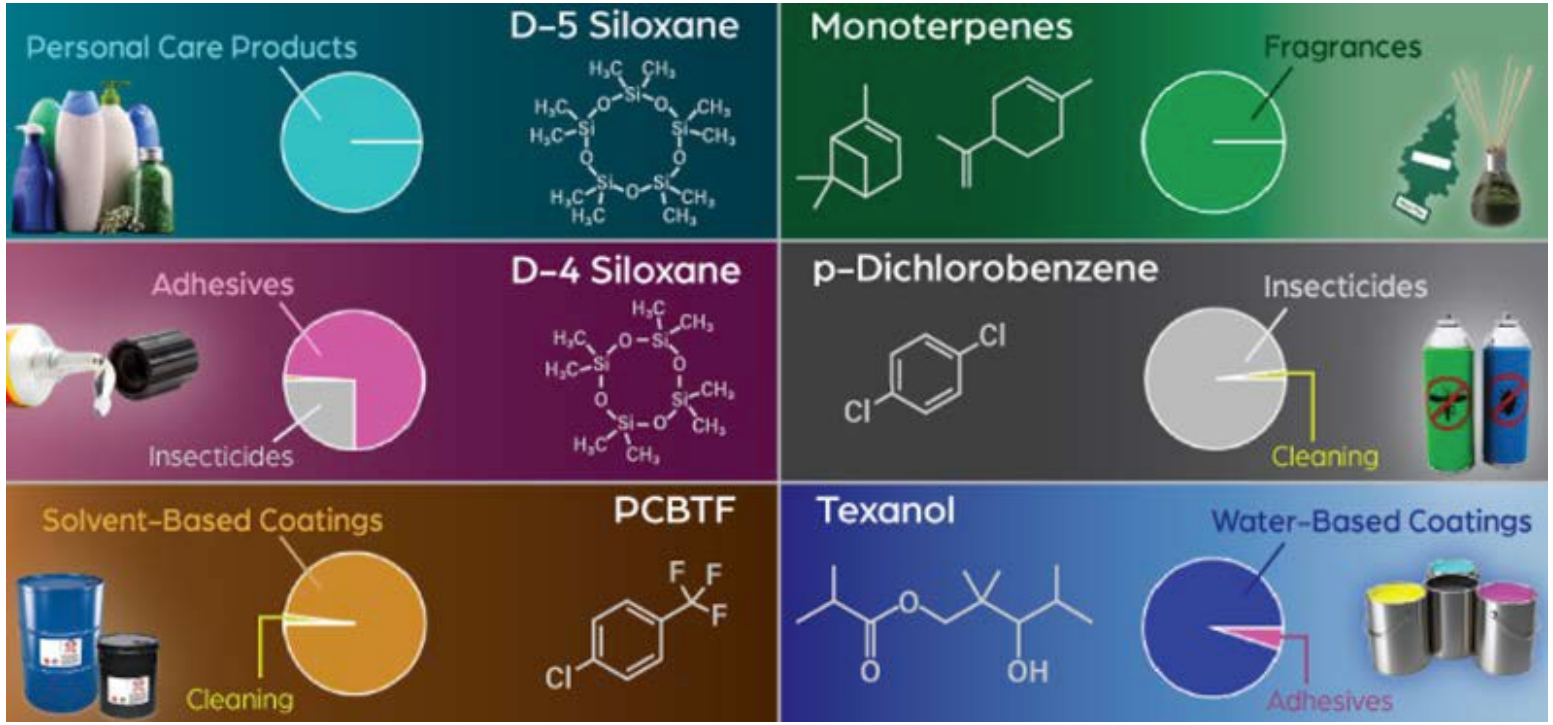
Ozone Chemical Mechanism
- Reduced number of species
- Simplified reactions

PM Chemistry
- Inorganic Aerosols
- Secondary Organic Aerosol

Model Evaluation

Volatile Chemical Products

- Volatile Chemical Products (VCP)
  - Paints
  - Solvents
  - Adhesive
  - Cleaning products
  - Printing inks
  - Pesticides
  - Personal care products

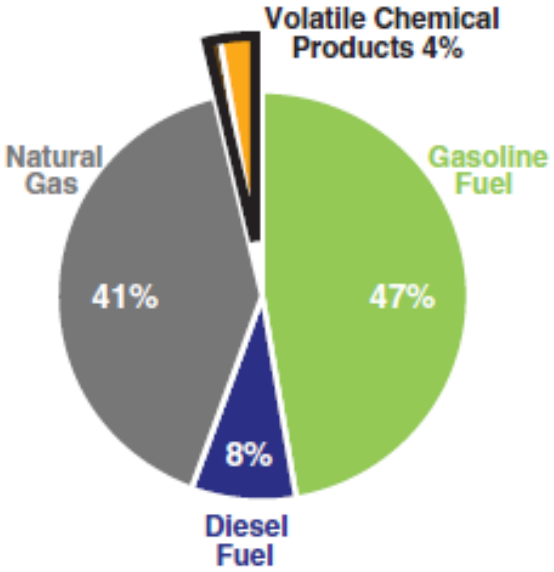


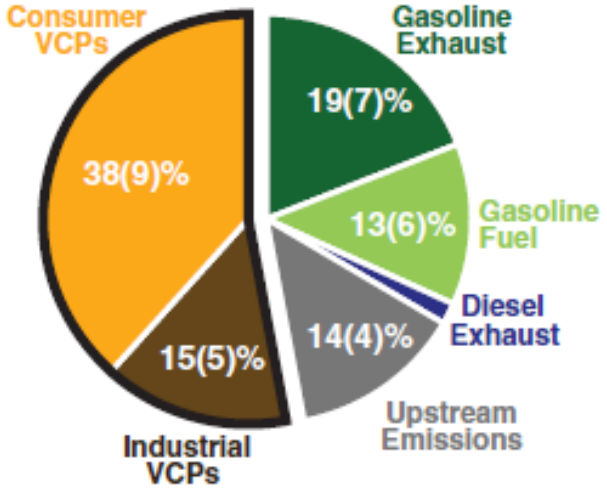
Gkatzelis et al., *Environ. Sci. Technol.*, 2021

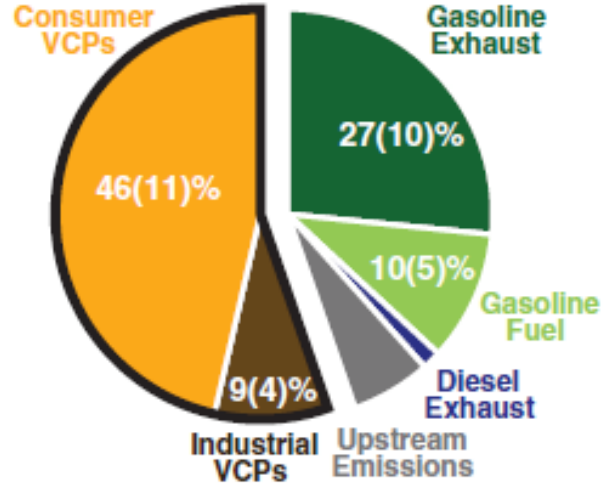
- VCP contain and emit **V**olatile **O**rganic **C**ompounds (VOC)

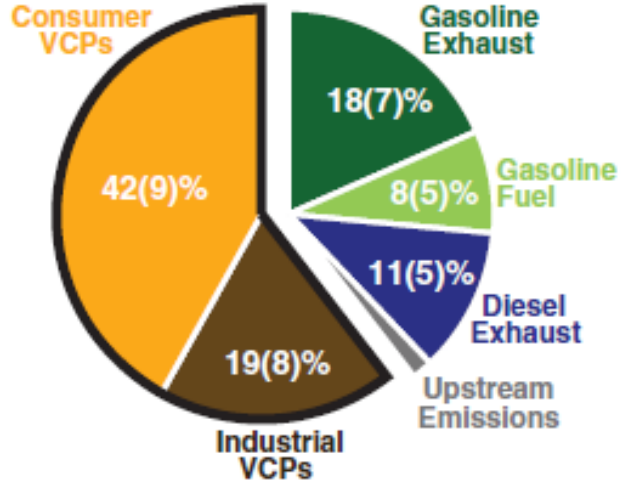
Impact of VCP

- Smallest percentage of product use
- Significant contribution to VOC emissions and reactivity
- Significant contribution to Secondary Organic Aerosol (SOA)







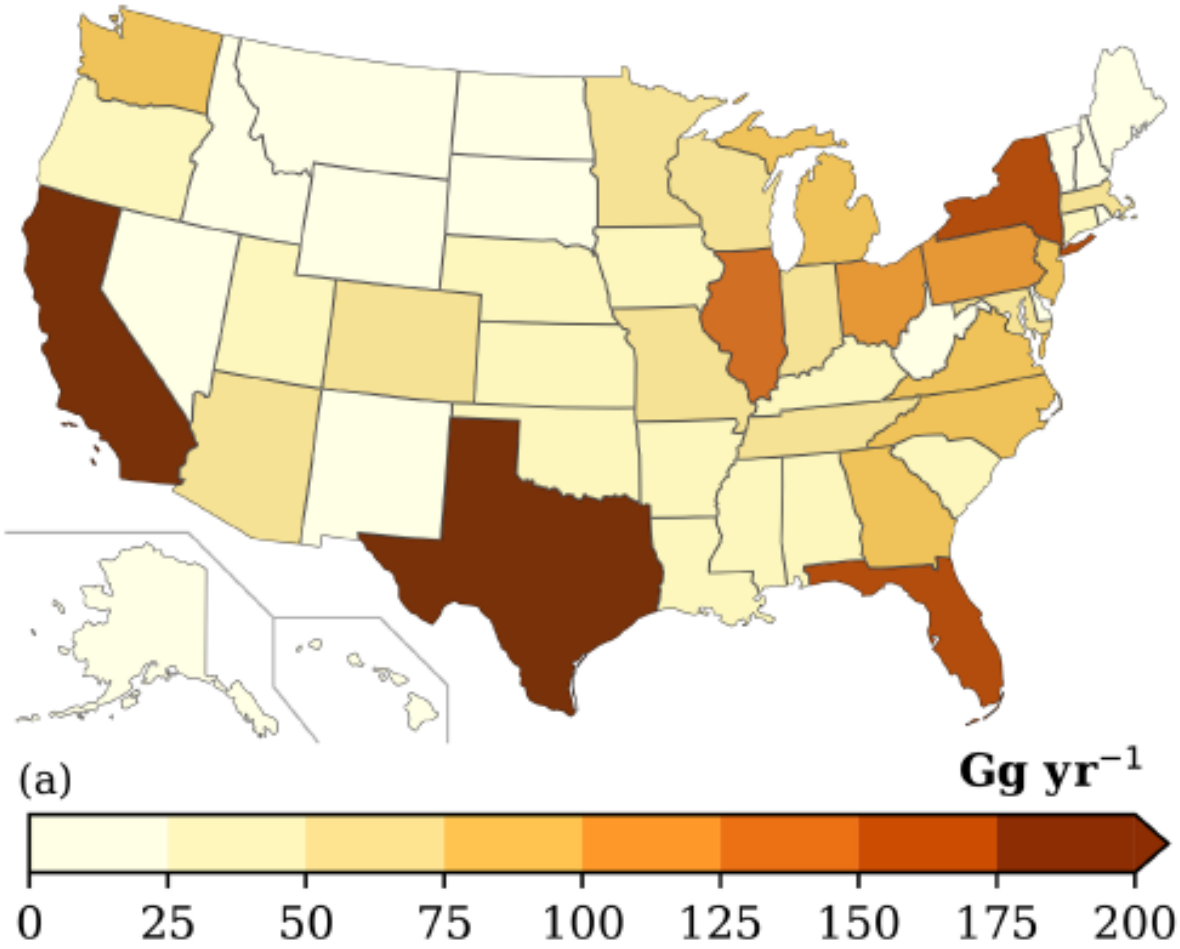


McDonald et al., *Science,* 2018

VCP Emissions

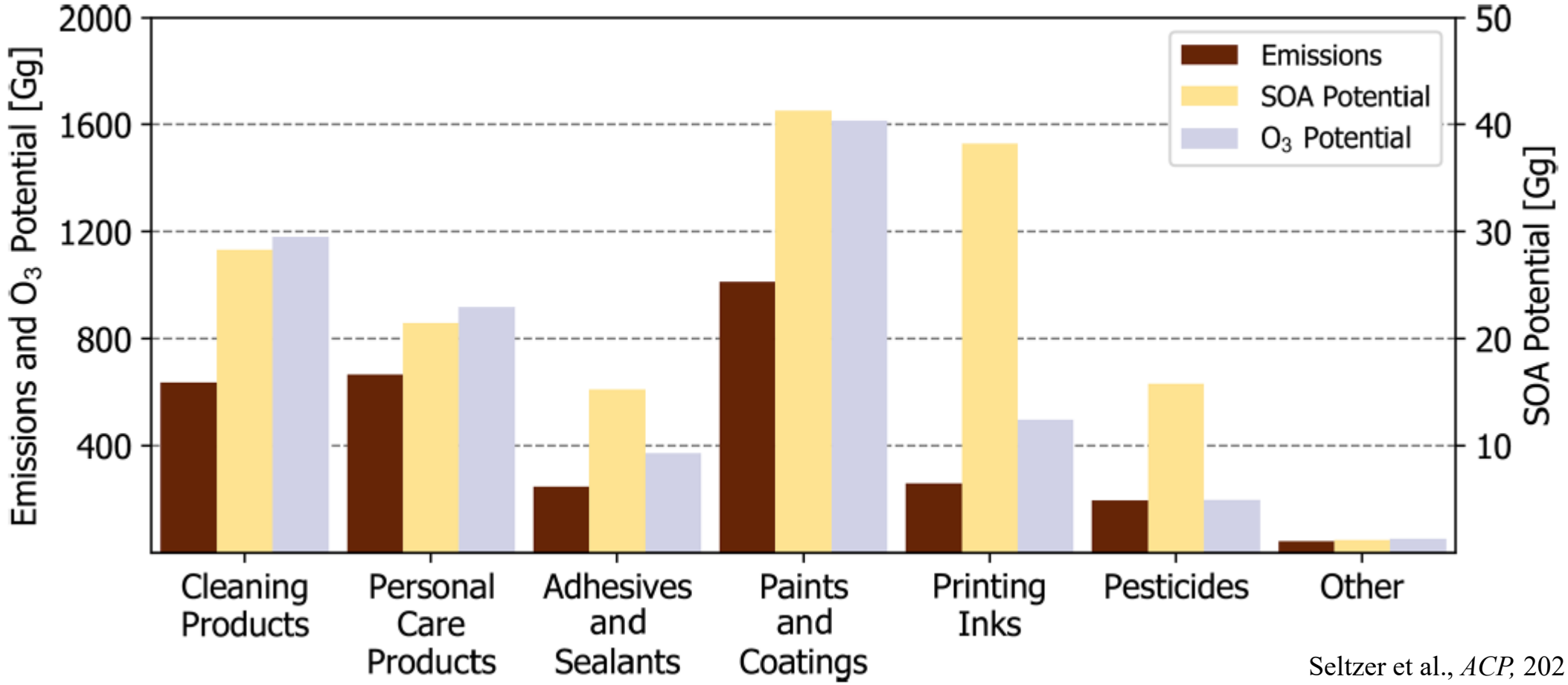
- Emissions vary throughout the country
- Highest emissions in California and Texas

VCP emissions by state



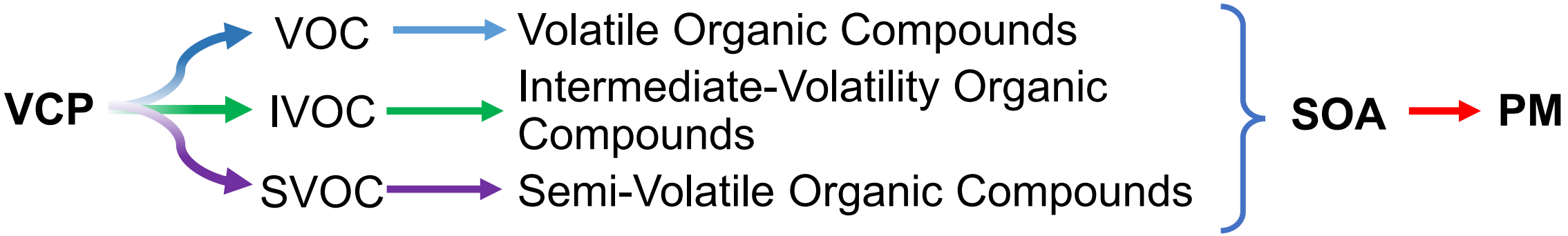
Seltzer et al., *ACP,* 2021

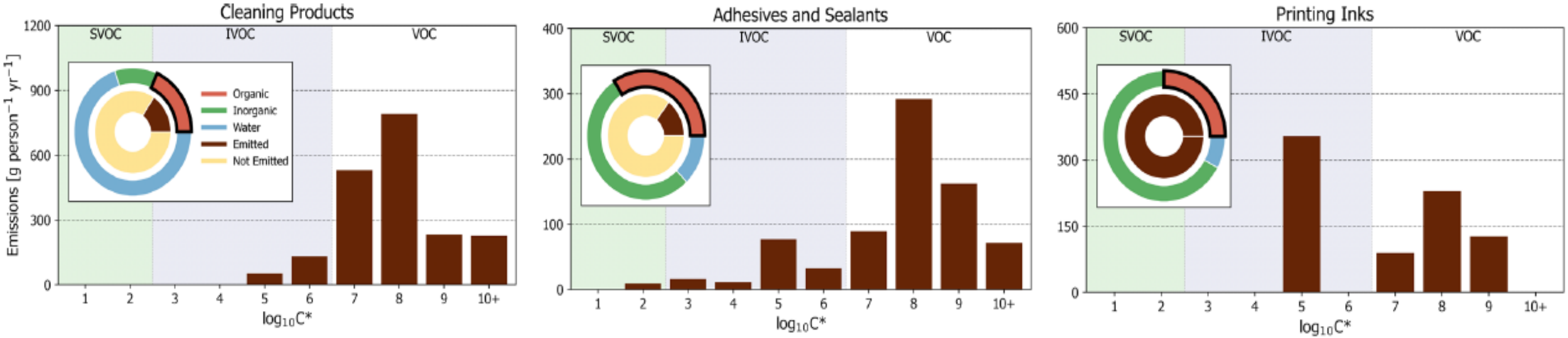
VCP Potential to Form Ozone and PM



Seltzer et al., *ACP,* 2021

Volatile Chemical Products and Particulate Matter

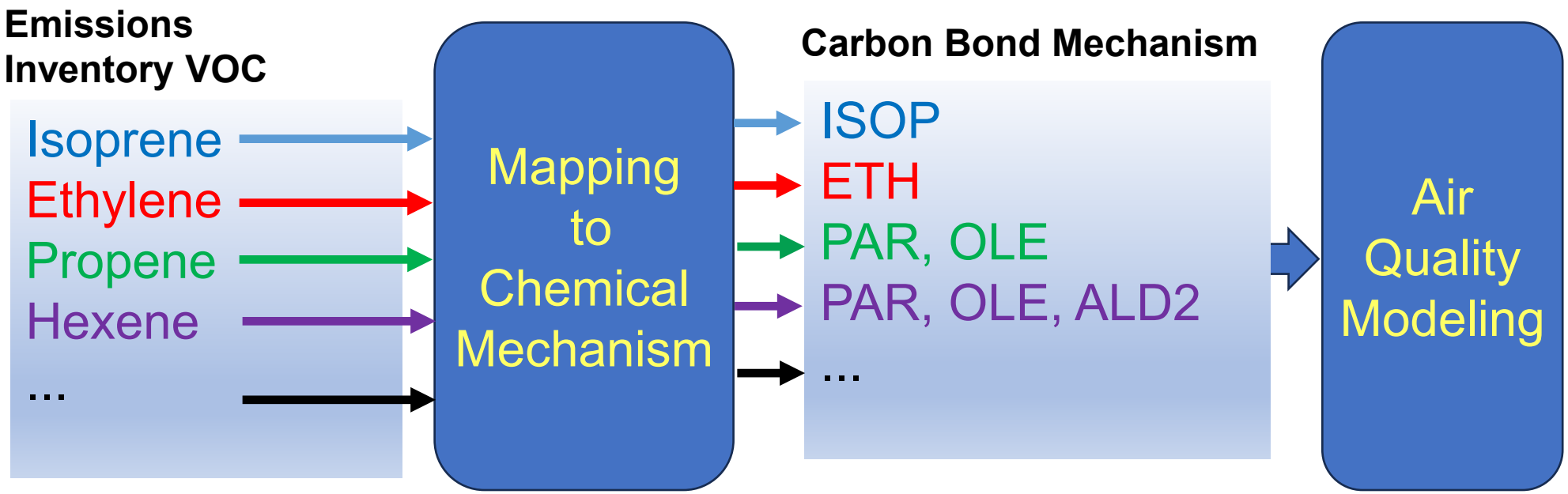




Seltzer et al., *ACP*, 2021

Carbon Bond Chemical Mechanism for Ozone

- Different chemical mechanism available
- Mechanisms have reduced number of compounds and simplified chemical reactions

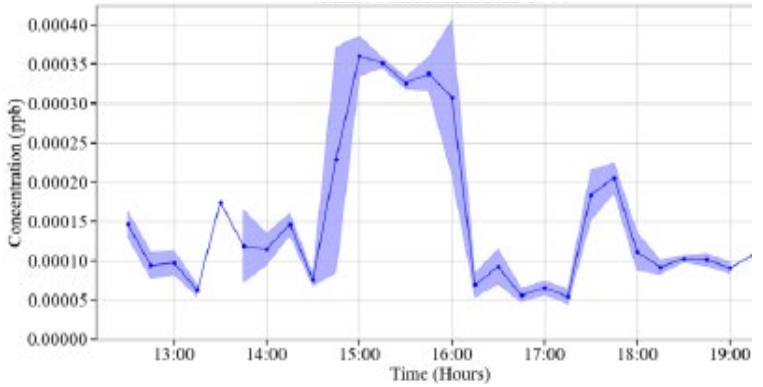


VCP Measurements in Houston

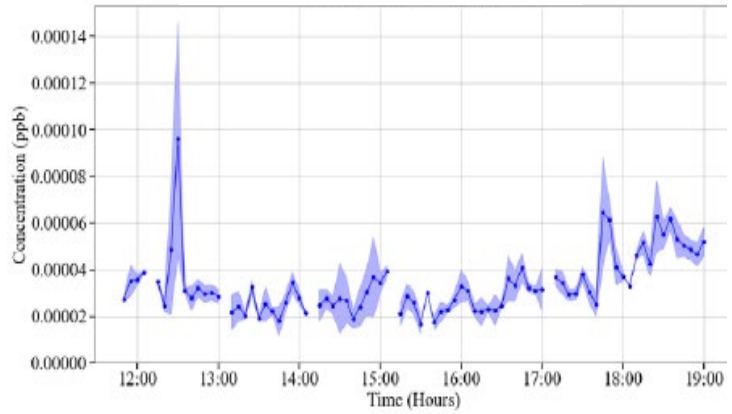
AIR QUALITY RESEARCH PROGRAM
PROJECT 22-020

- To characterize concentrations and spatial distributions
- Mobile lab measurements in Summer, Fall, and Winter
- Measured 61 VCP species
- Observed seasonal differences in some VCP

Texanol (Fall)



Texanol (Winter)

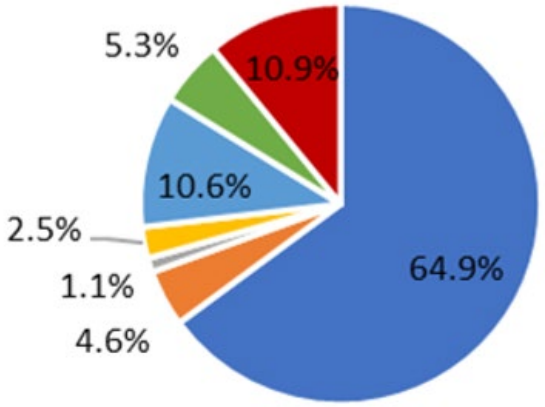


Chemical Mechanism Updates

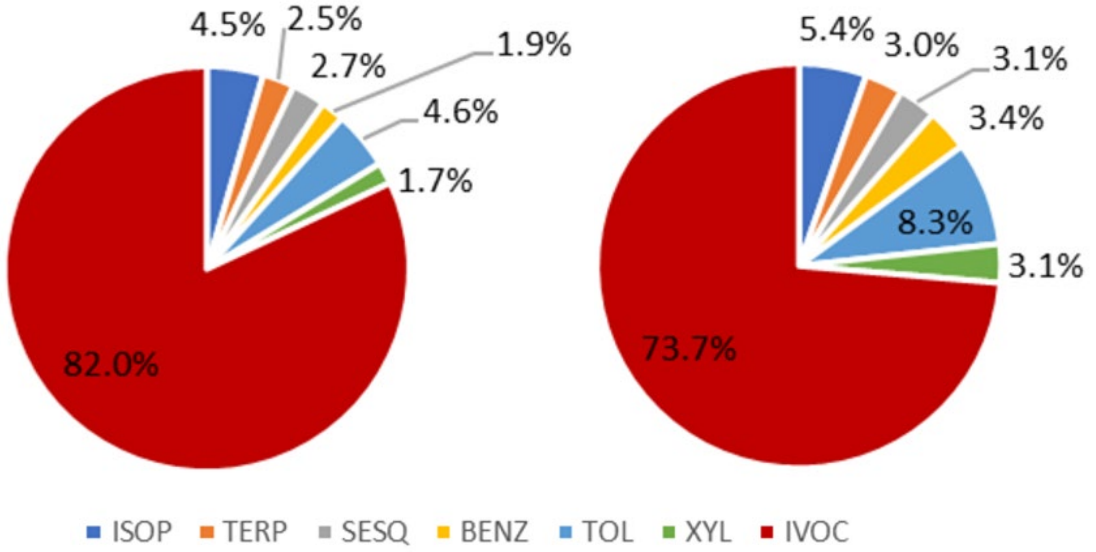
- Secondary Organic Aerosol (SOA) - new scheme with updated SOA yields (Ramboll, 2025)
- Addition of VCP (Ramboll, 2025)
  - Emitted explicit compounds
  - Emitted lumped species
  - Intermediate reaction mechanism species

PROJECTS Ramboll 2024/2025

Emissions



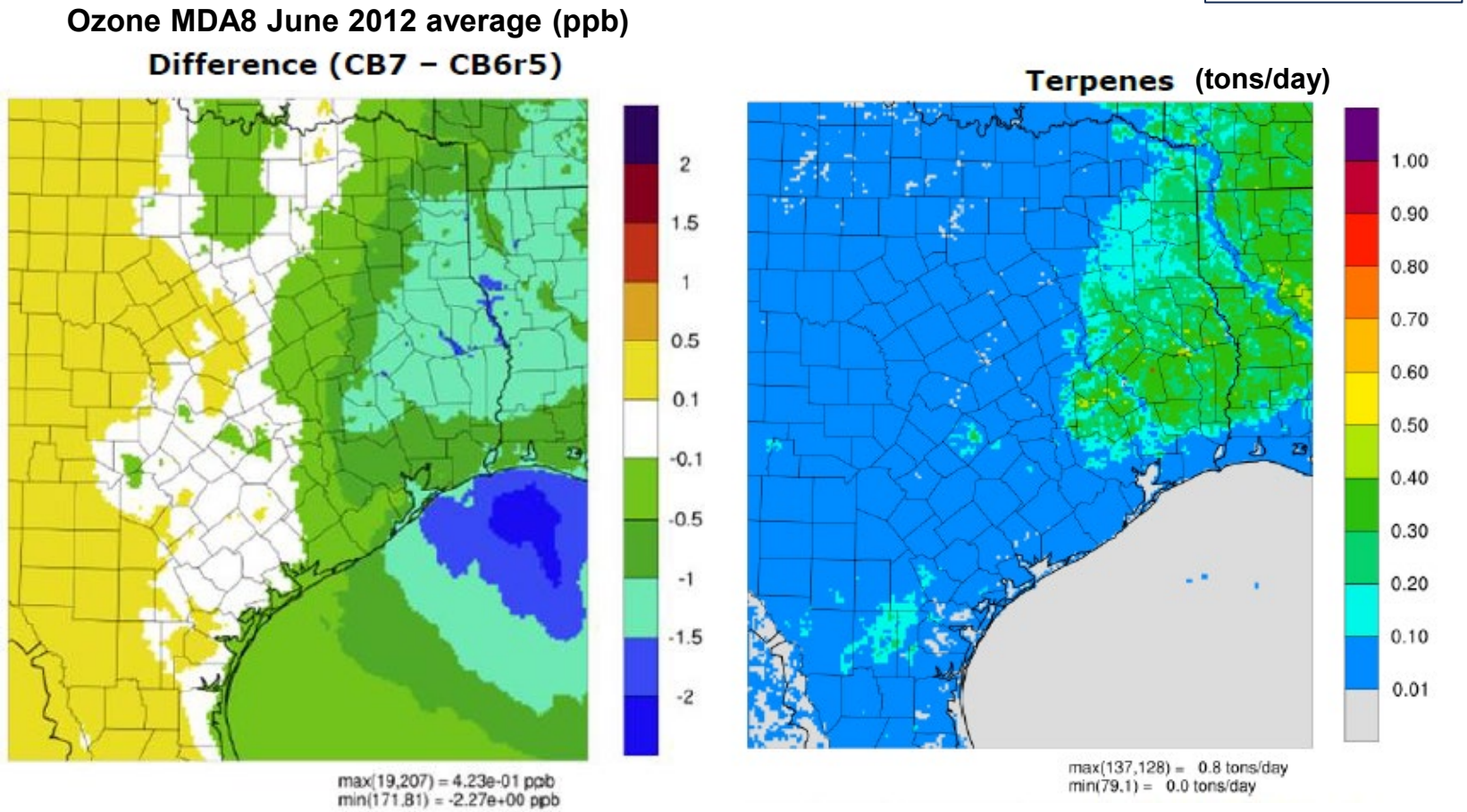
SOA potential of precursors



Chemical Mechanism Update: Carbon Bond 7

PROJECT
Ramboll 2021

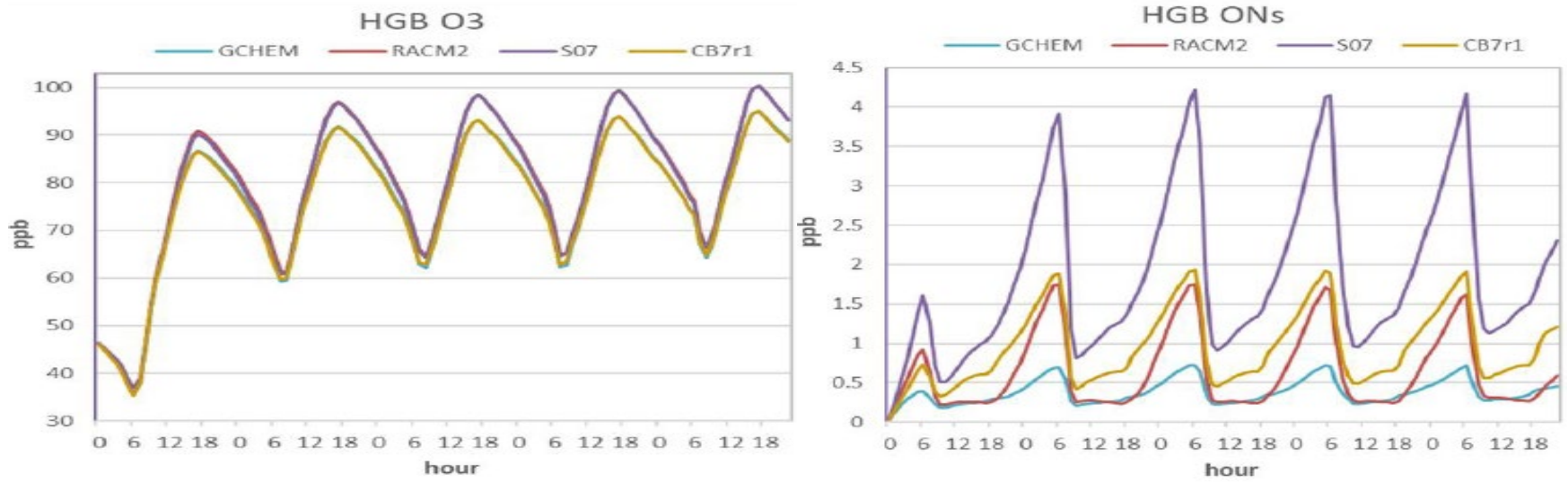
- Based on CB6 revision 6
- Updated chemistry
  - Isoprene
  - Terpene
  - Large alkanes
  - Iodine
  - Radicals
- 74 new or updated reactions

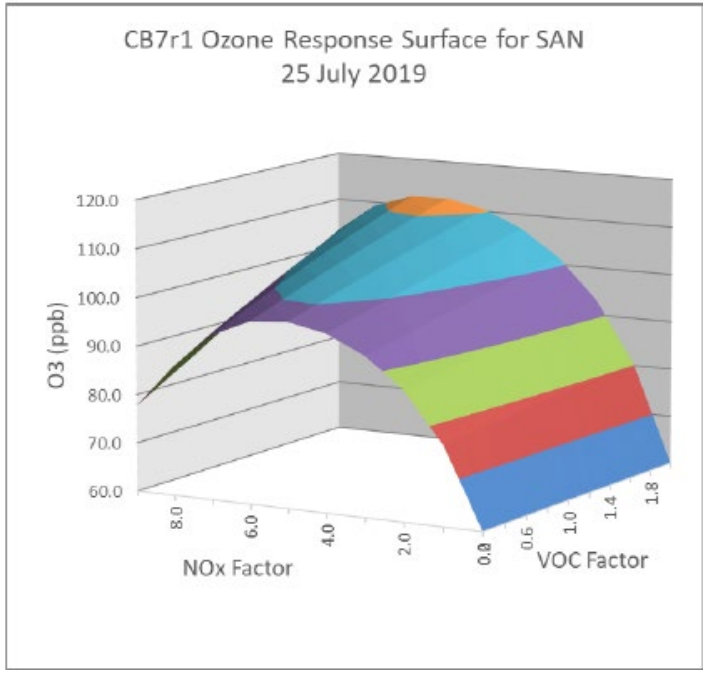


Comparison of Chemical Mechanisms for Ozone

PROJECT
Ramboll 2023

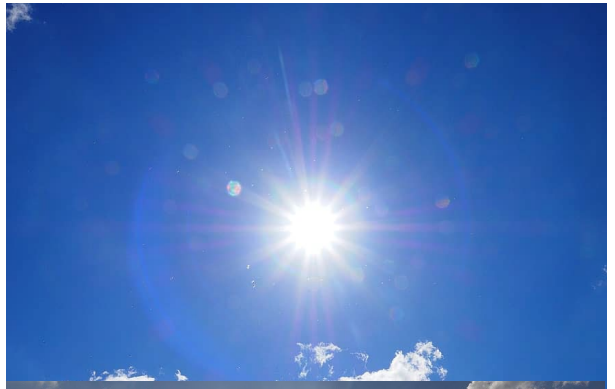
- Evaluate ozone estimation and response to emissions
  - Mechanisms agree for ozone and most of other species
  - Significant differences for organic nitrates and peroxyacyl nitrates
  - Similar ozone responses to varying emissions

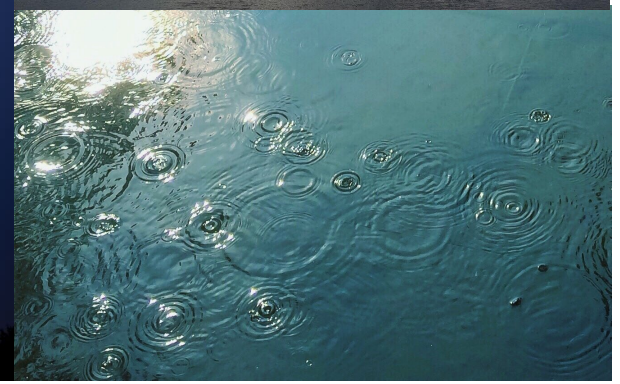




Meteorology Modeling for Air Quality

- Temperature
- Pressure
- Wind speed and direction
- Clouds
- Rain
- Lightning
- Mixing height





Updates to Modeling Convective Rain

- Motivation
  - Uncertainties in timing and location of convective rainfall in meteorological model.
- Goal
  - Improve representation of convective rainfall in meteorological modeling.
  - Improve ozone modeling.

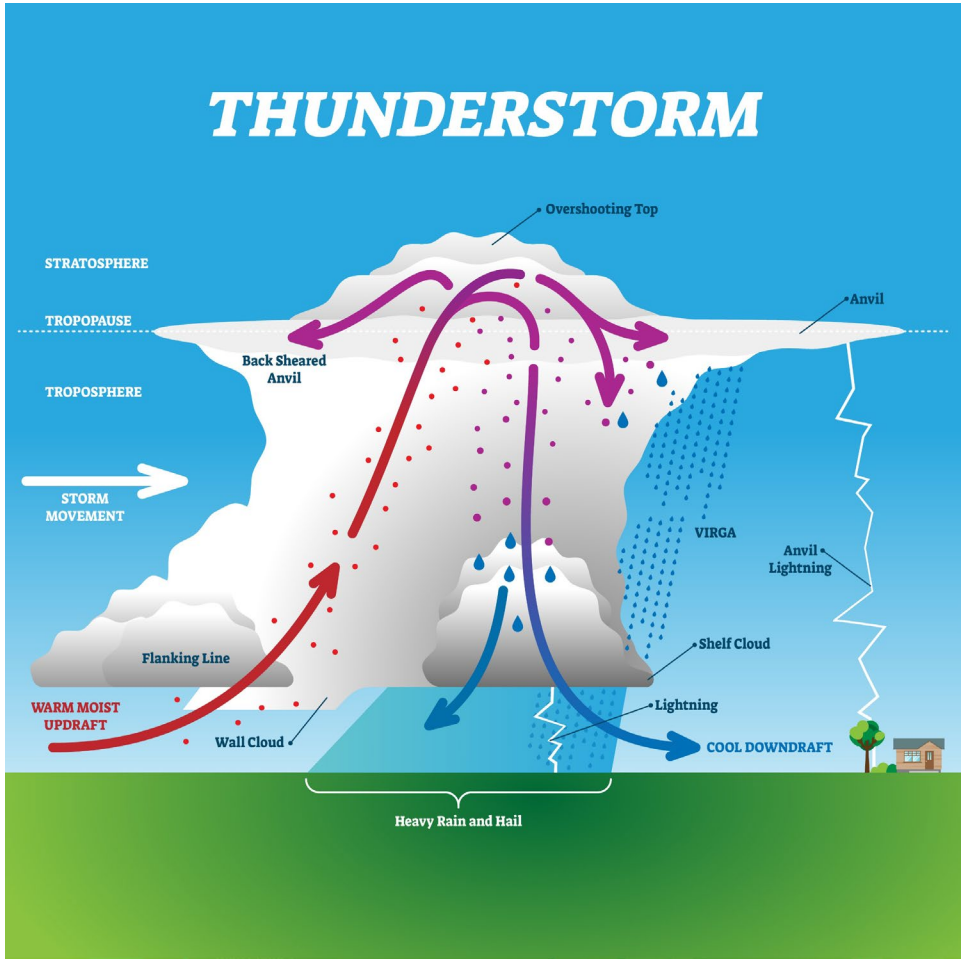
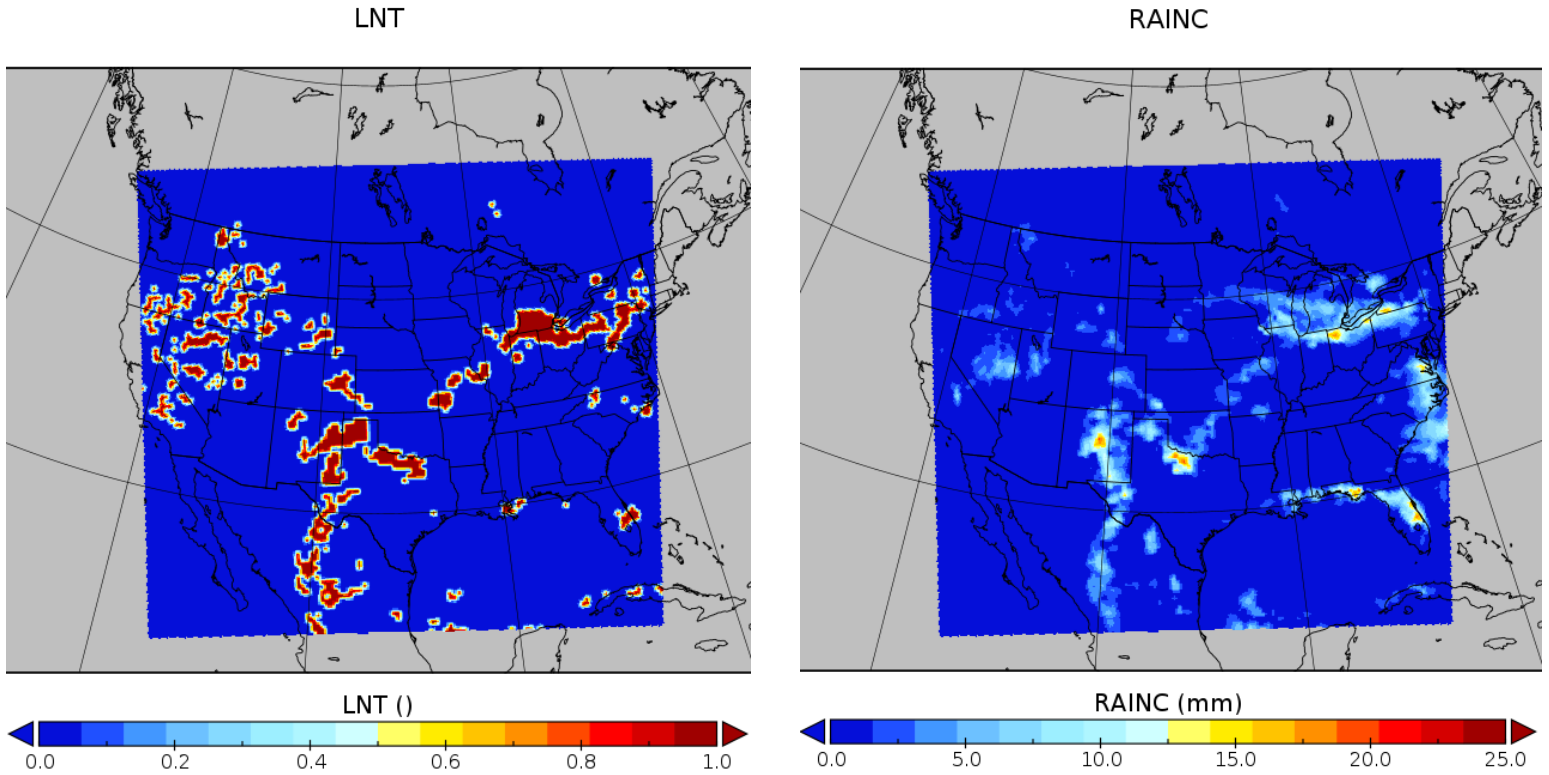


Image Courtesy of Royal Meteorological Society

Lightning Data Assimilation (LDA)

PROJECT AER 2022

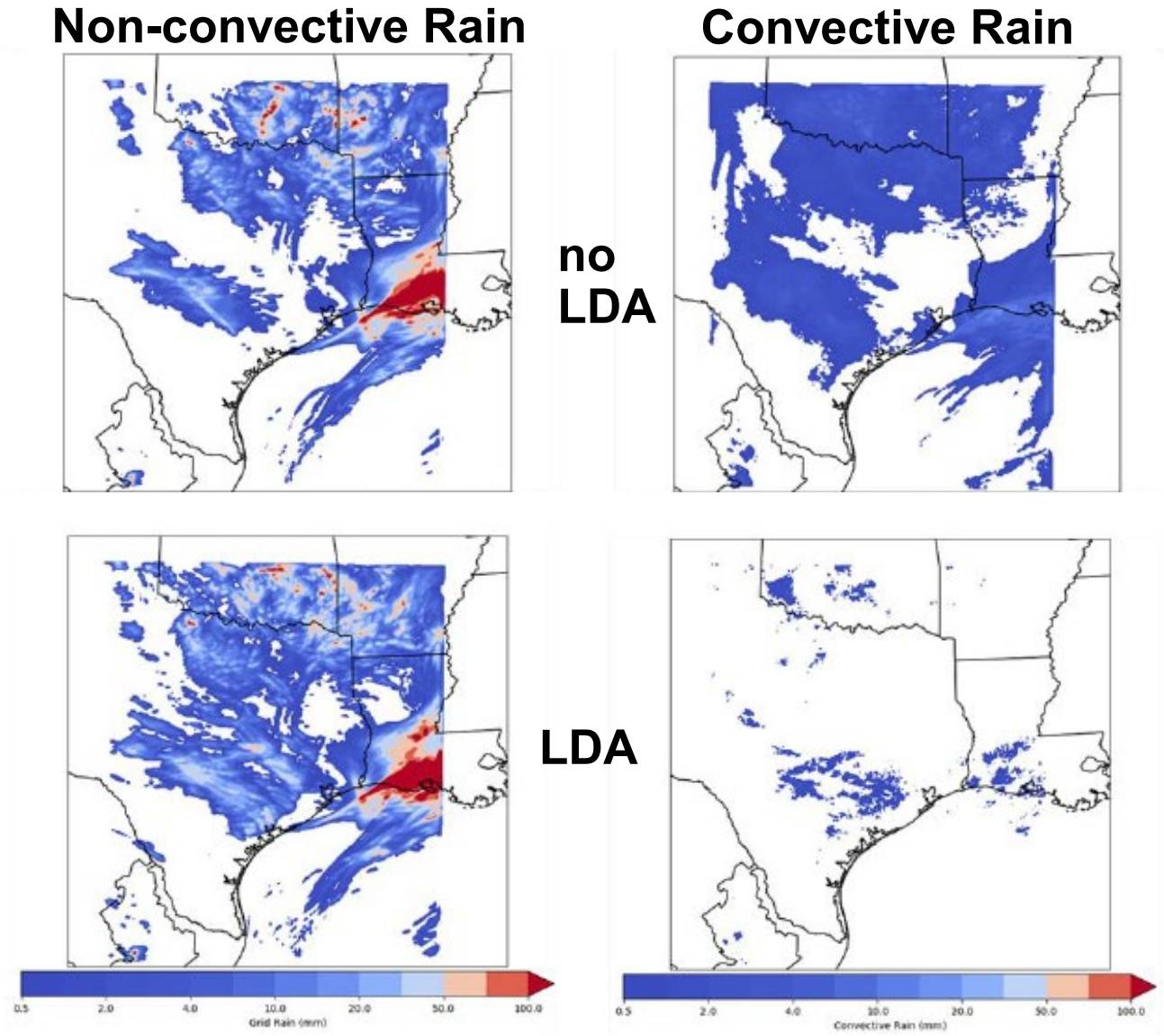
- Method: Use lightning observations to force deep convection where lightning is observed and shallow convection if lightning is not present.



Impact of LDA

PROJECT AER 2022/24

- Suppressed precipitation where lightning did not occur.
- Little impact on temperature, wind, and ozone.



Planetary Boundary Layer (PBL)

- Layer of air above the Earth surface
- Known as “Mixed Layer”
- Important for mixing of pollutants
- Mixing height varies with time
- Mixing height
  - Calculated by meteorological models
  - Limited observed data
  - Research to determine height from weather radars
  - Special measurement campaigns

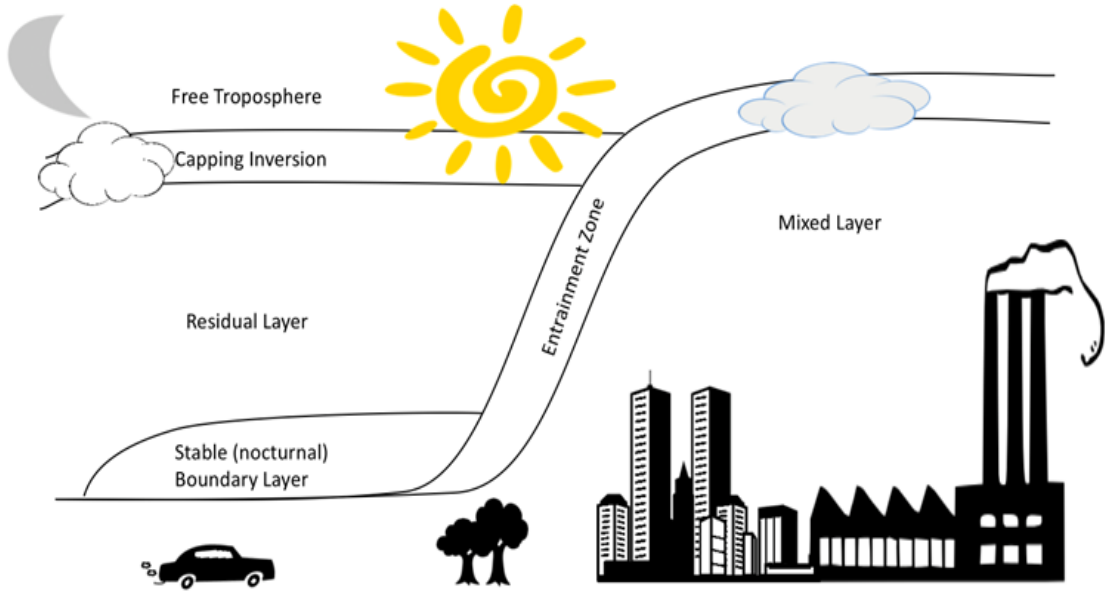
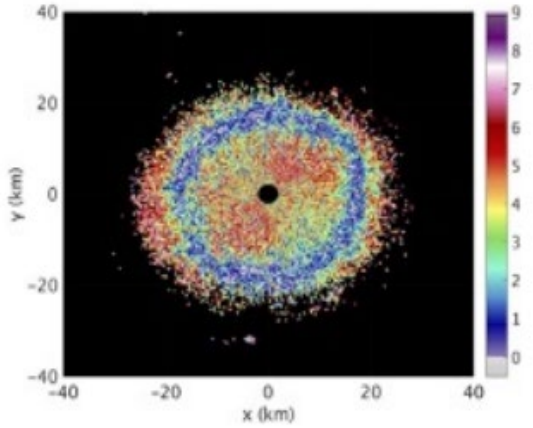


Image from Hampton University

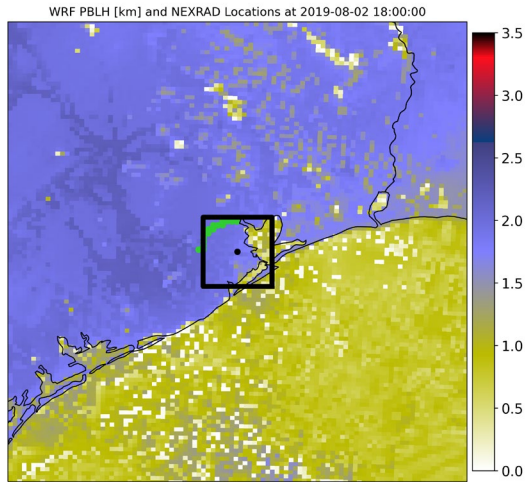
Mixing Height Retrieval and Estimation

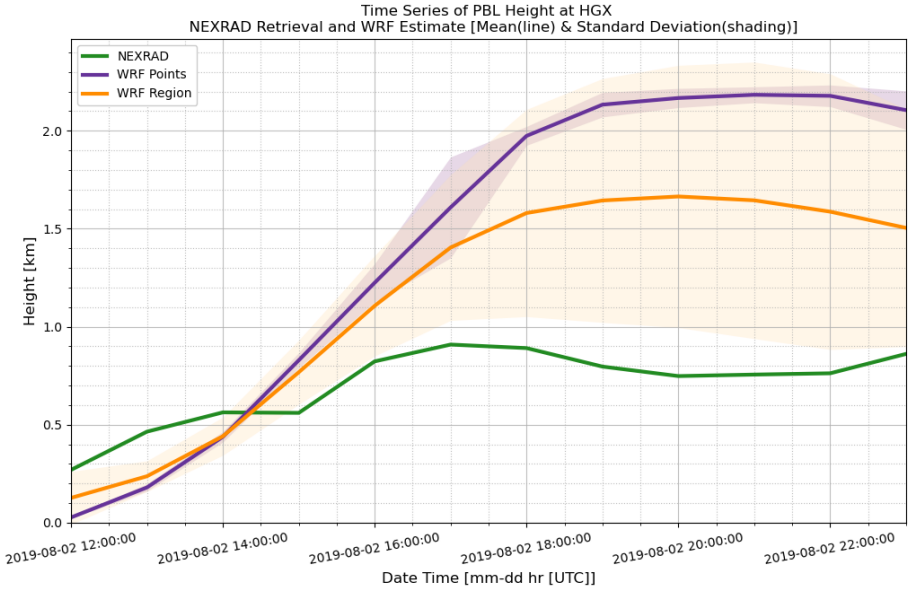
PROJECTS
AER 2022/23

- Development of software for mixing height estimation based on National Weather Service (NWS) radars
- Evaluation of modeled and radar-estimated mixing heights



Differential reflectivity

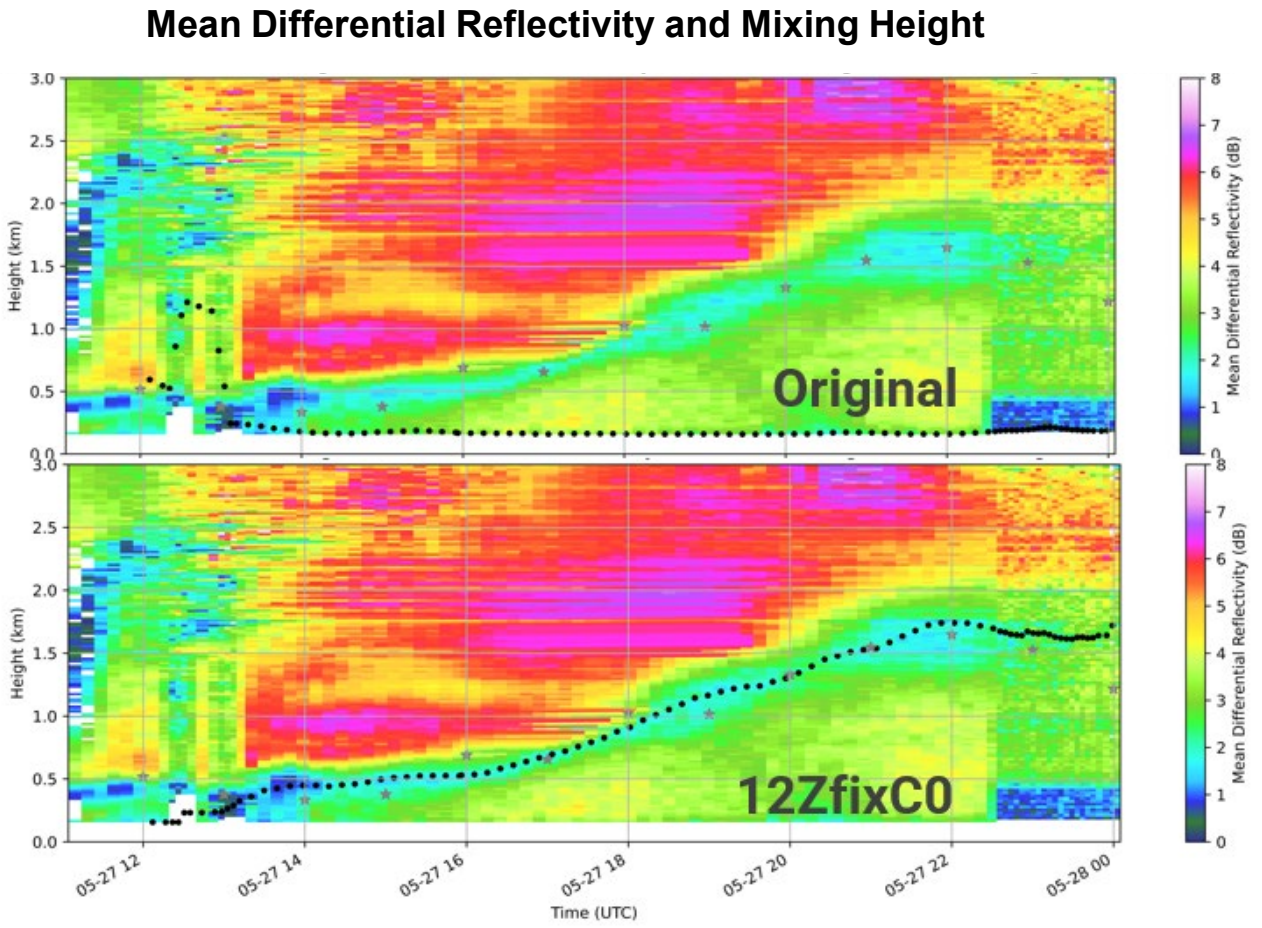




Mixing Height Retrieval Improvements

PROJECT AER 2024

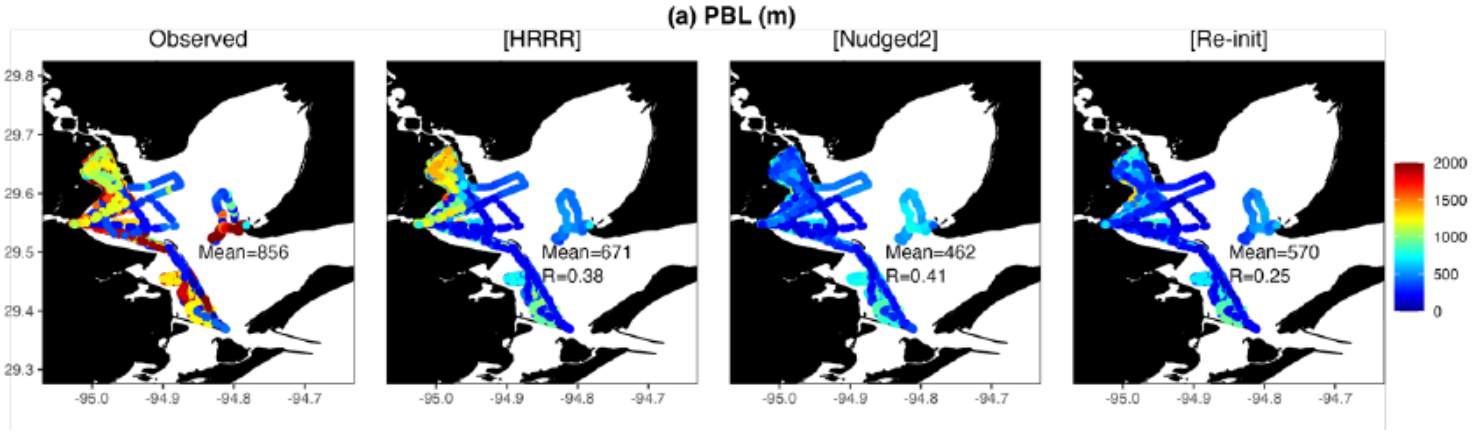
- Further validation of mixing height estimation using
  - Aircraft Meteorological Data Relay (AMDR)
  - TRACER-AQ sonde-based data
- Improvement of mixing height estimation method

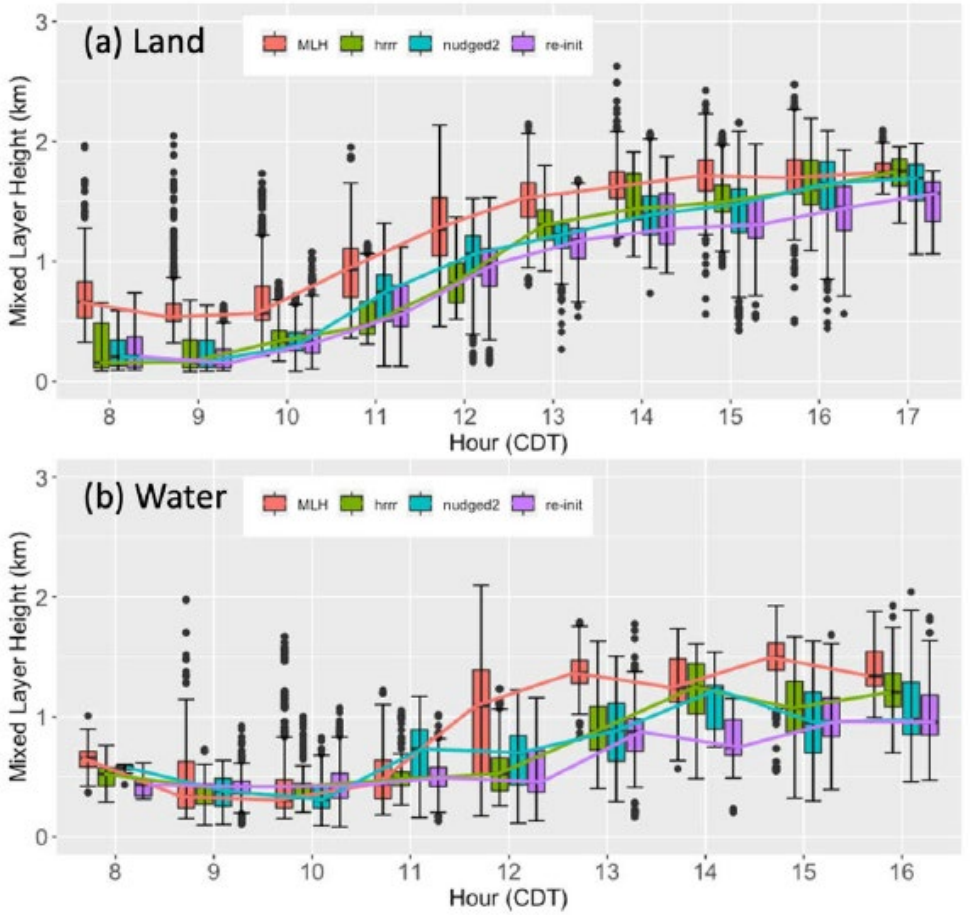


Meteorological Model Configuration Testing

AIR QUALITY RESEARCH PROGRAM
PROJECT 22-008

- WRF configurations
  - PBL representation
  - Microphysics
  - Nudging
  - Initialization dataset

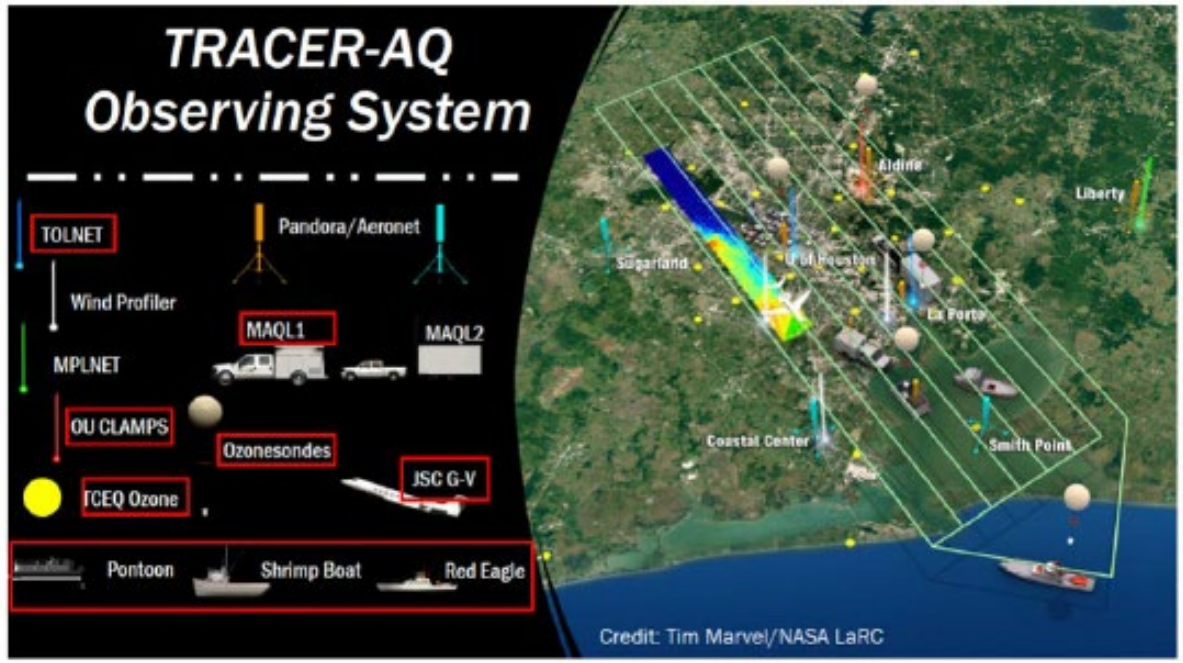




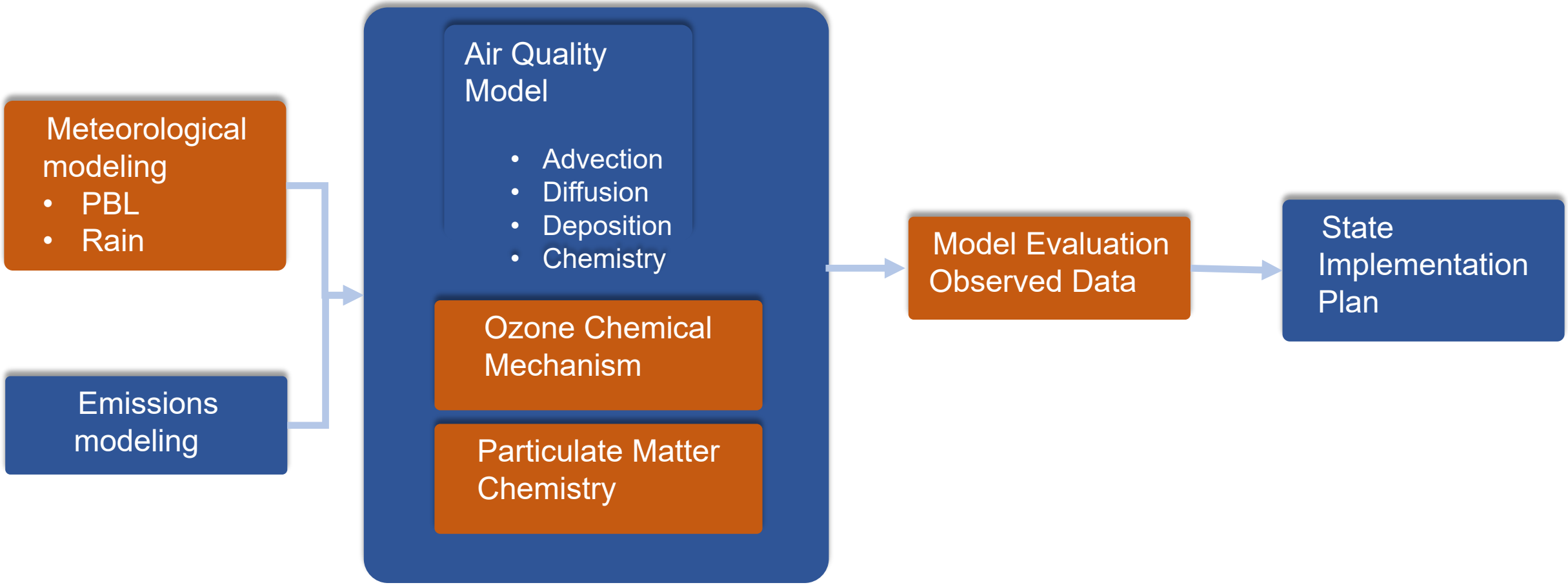
Field Studies and Evaluation of Models

PROJECTS
Ramboll 2025
AER 2025

- Field study in 2022 and 2023
- Measurements
  - Over land
  - Over water
  - Vertical profiles
- Enhanced air quality model evaluation of 2022 modeling platform
- Meteorological model configuration tests for 2022



Research Areas Summary



Questions?

Beata Czader

beata.czader@tceq.texas.gov

TCEQ, Office of Air, Air Quality Division

References

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- Ramboll, 2025: Updating CAMx's Treatment of VCP/IVOC to Target SOA Precursor Emissions More Precisely (in progress)
- Ramboll, 2025: Extended Observation Data for the 2022 Modeling Platform Performance Evaluation (in progress)