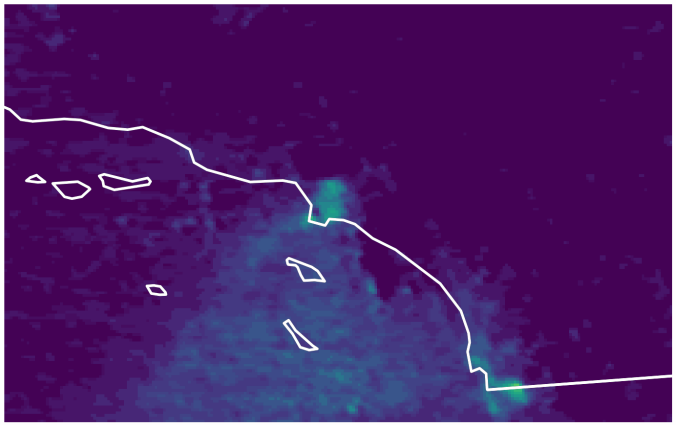
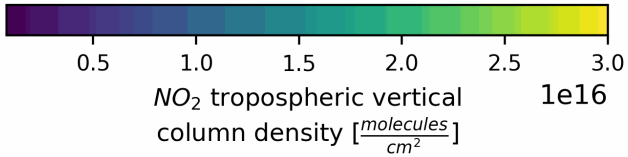
New viewpoint on air pollution from TEMPO

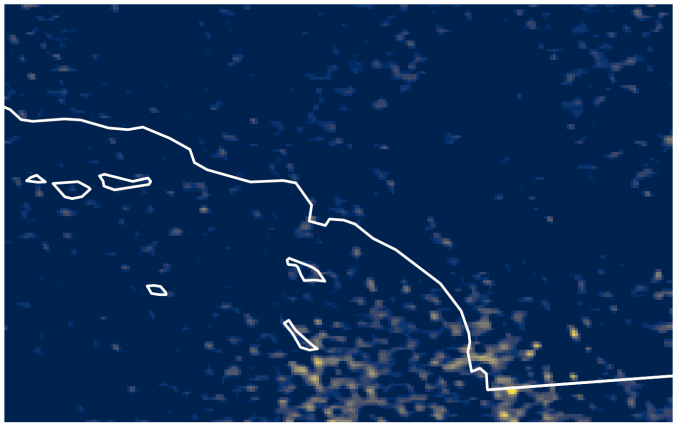
Palisades Fire - 2025/01/07

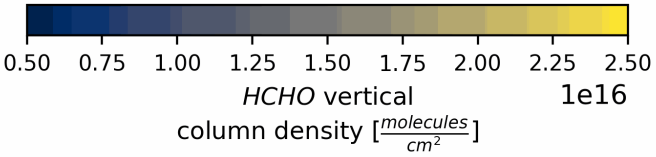
TEMPO NO_2



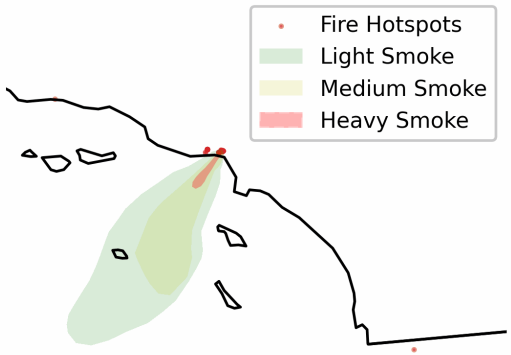


TEMPO *HCHO*





NOAA HMS
smoke and fire data



Joseph Palmo (MIT)

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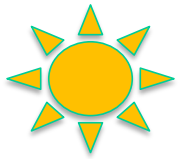
DEPARTMENT OF EARTH, ATMOSPHERIC AND PLANETARY SCIENCES
ATMOSPHERIC CHEMISTRY

HAQAST Meeting
Washington University of St. Louis
November 6, 2025

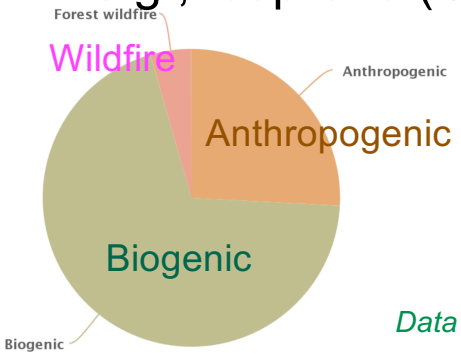
Background Info: Ground-level ozone forms through atmospheric photochemistry; Satellites don't directly measure ground-level ozone

formaldehyde
HCHO



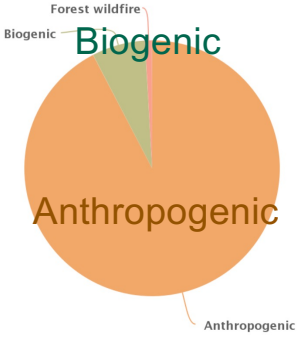
nitrogen dioxide
NO_2

Volatile Organic Compounds (VOCs)
e.g., Isoprene (C_5H_8)



OZONE (O_3)

Nitrogen Oxides (NO_x)
= NO + NO_2

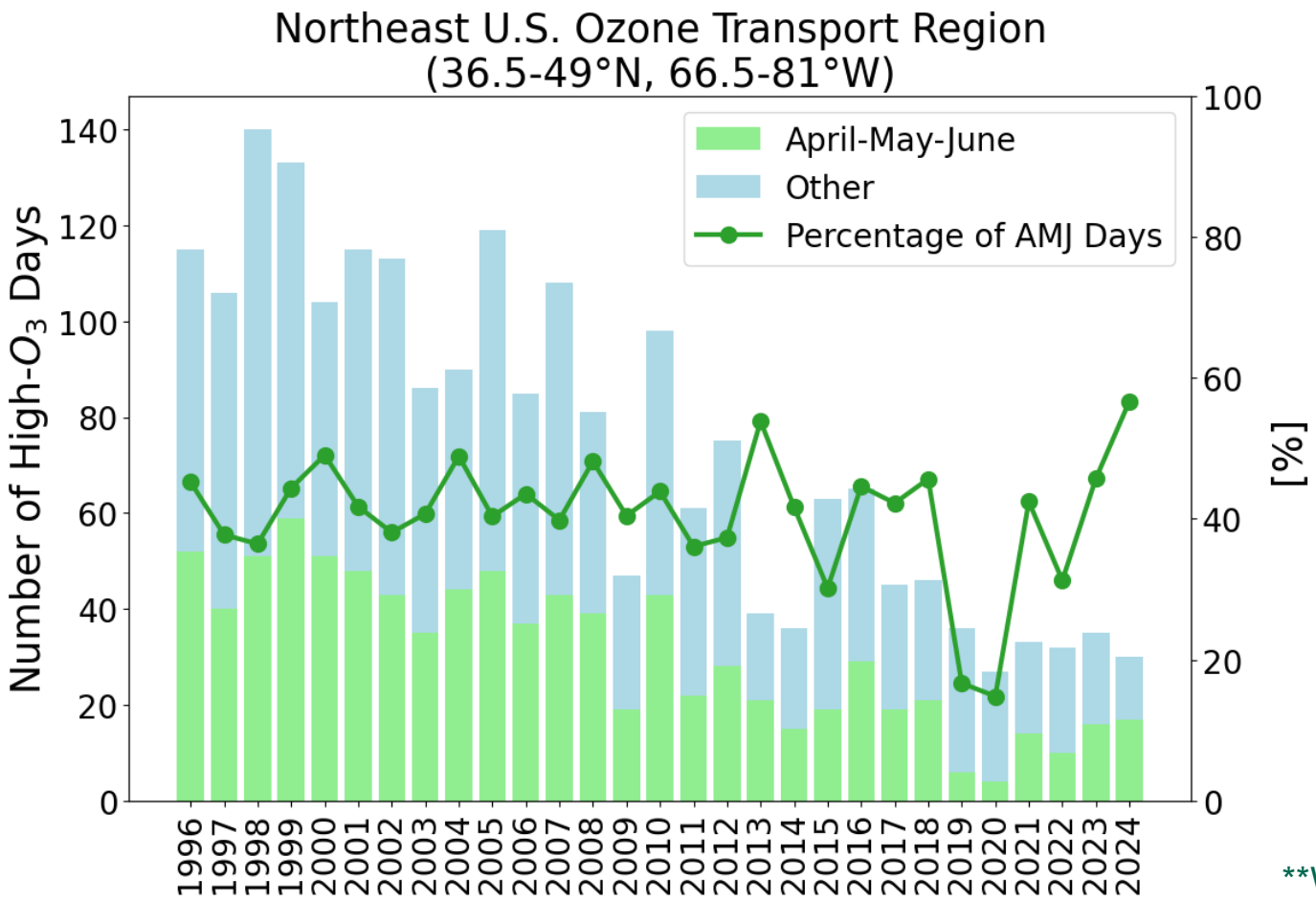


Data source: U.S. EPA 2014 National Emissions Inventory

How does local-to-regional **ozone-forming chemistry** change in space and time?

→ prior work establishes HCHO/NO_2 as a qualitative indicator of sensitivity to NO_x vs. VOC [*e.g., Tonnesen & Dennis, 2000; Martin et al., 2004; Duncan et al., 2010; Jin & Holloway, 2015; Jin et al., 2017; 2020; Schroeder et al., 2017; Souri et al., 2020; Tao et al., 2022*]

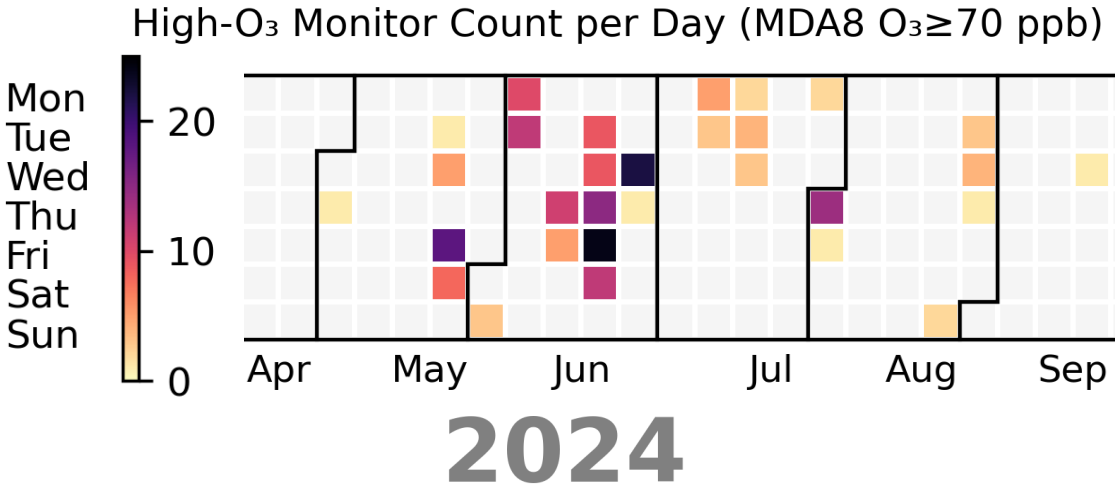
Challenge #1: What controls early-season high-ozone events in the Northeastern U.S. ozone transport region?

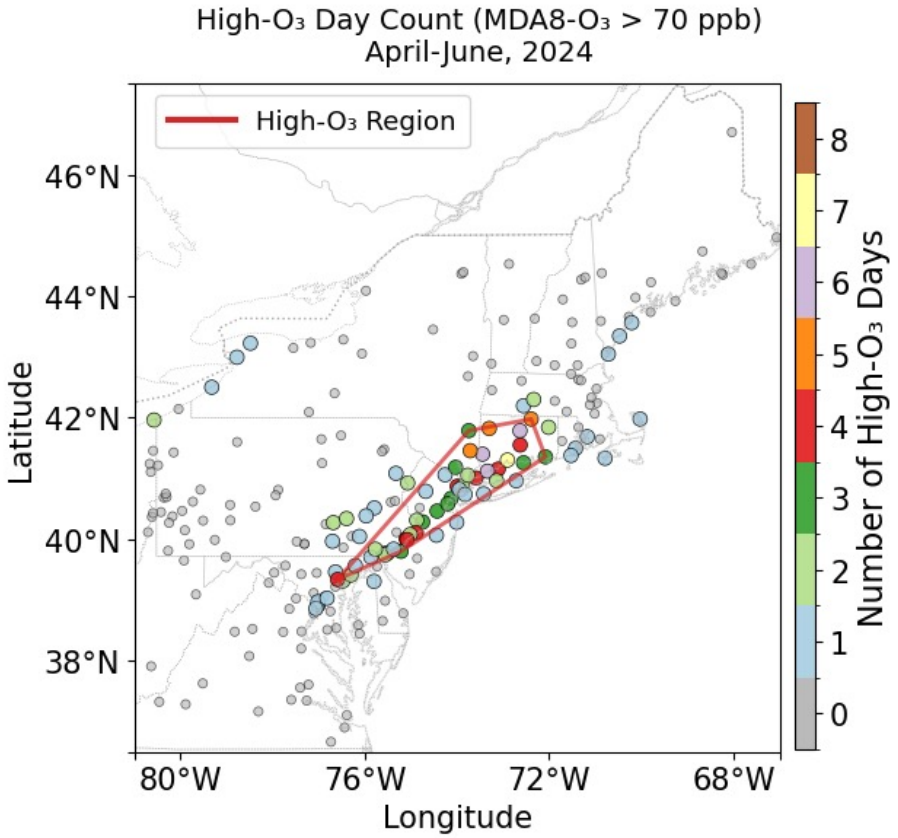


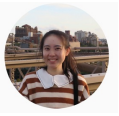
Madankui Tao (MIT)

Work in progress

When and where are the highest ozone events in the Northeast during 2024?

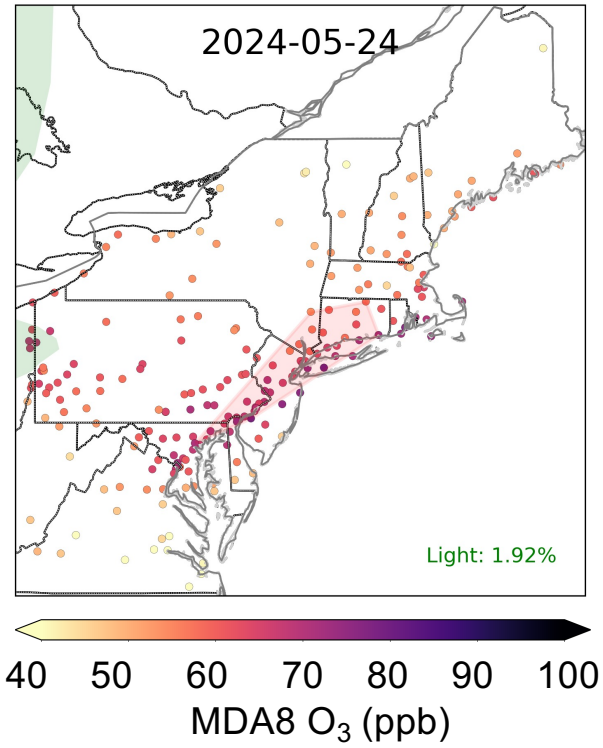


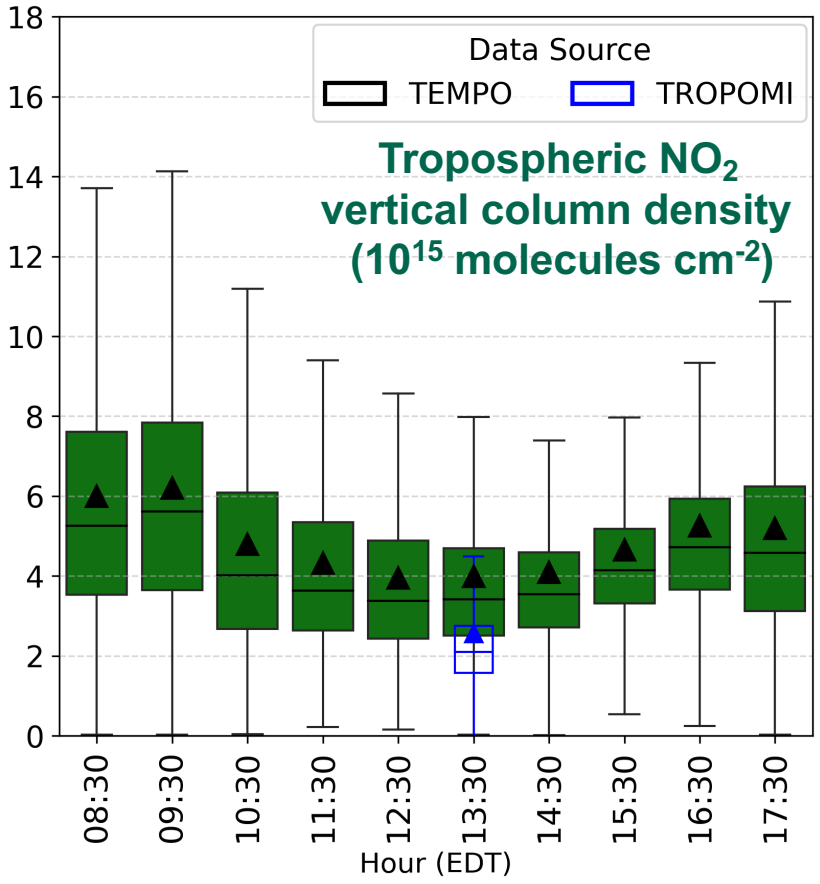




Madankui Tao (MIT) **Work in progress**

May 24th 2024: Combined view from TEMPO and meteorology implies regional photochemical ozone production





Morning NO_2 16% higher than May 2024 mean
stagnant winds
high temperature

→ **suggests "typical" regional photochemical production**

Madankui Tao (MIT) **Work in progress**

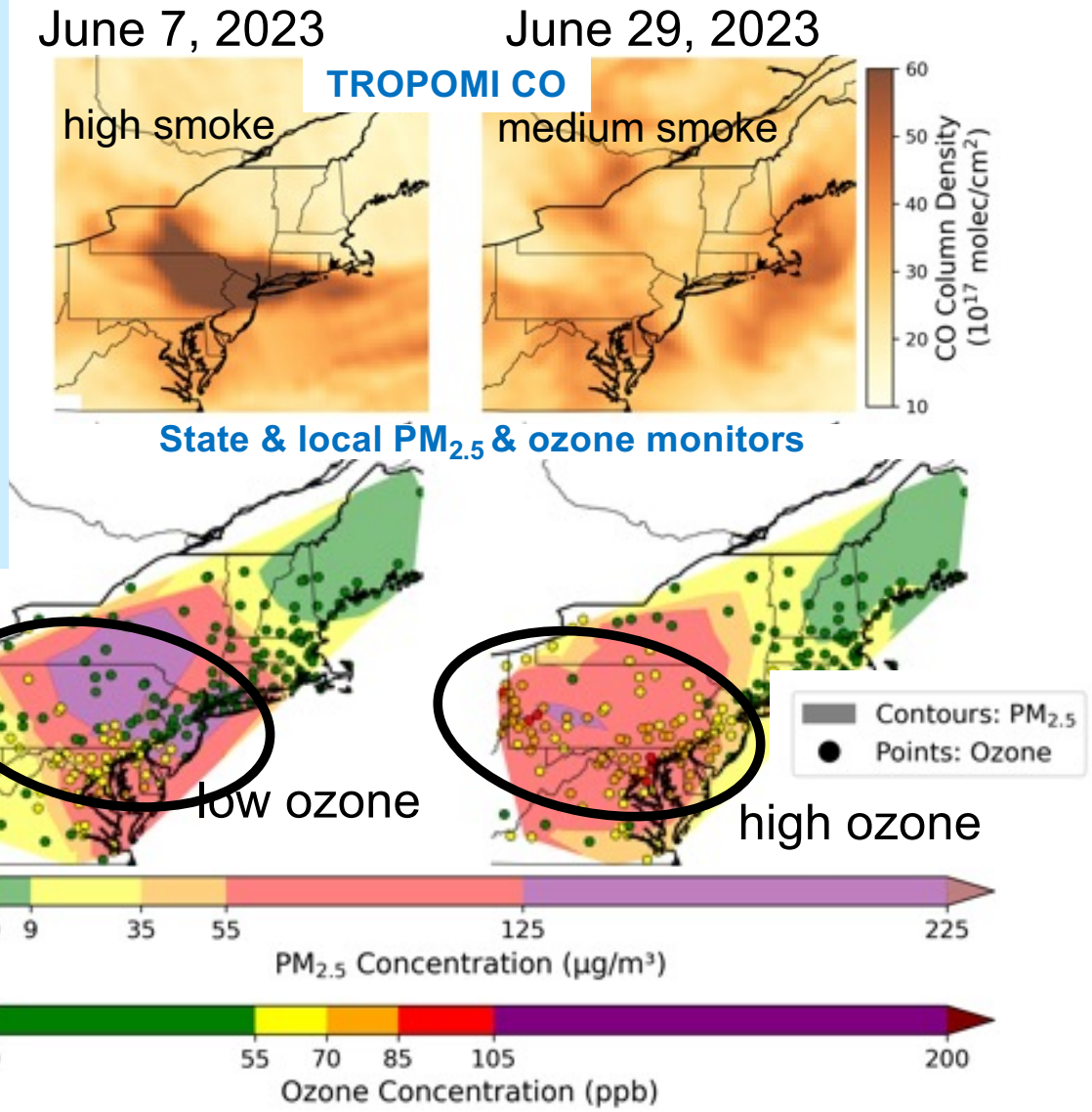
TEMPO v03 data; will update to v04 once 2024 is fully processed

Challenge #2:
How much ozone is produced by wildfires?

Is the ozone produced in transit
or
after the smoke mixes with urban NO_x (and thus controllable)?

June 7, 2023: Canadian wildfire plumes hit NYC

J. Palmo **Work in progress**



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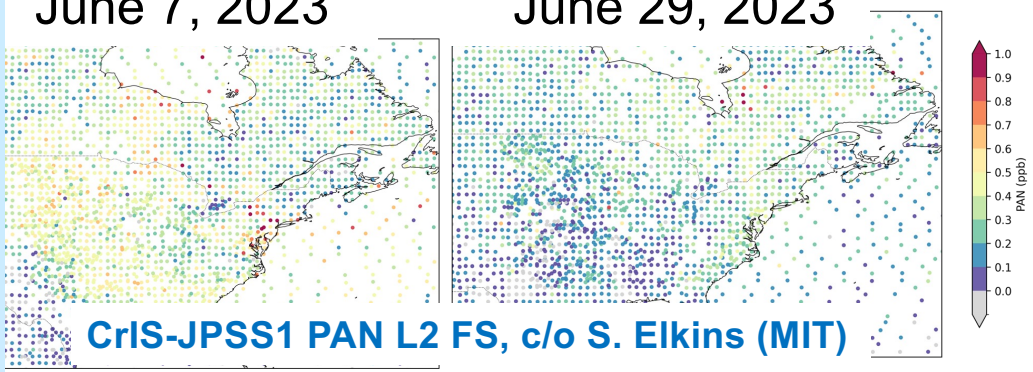
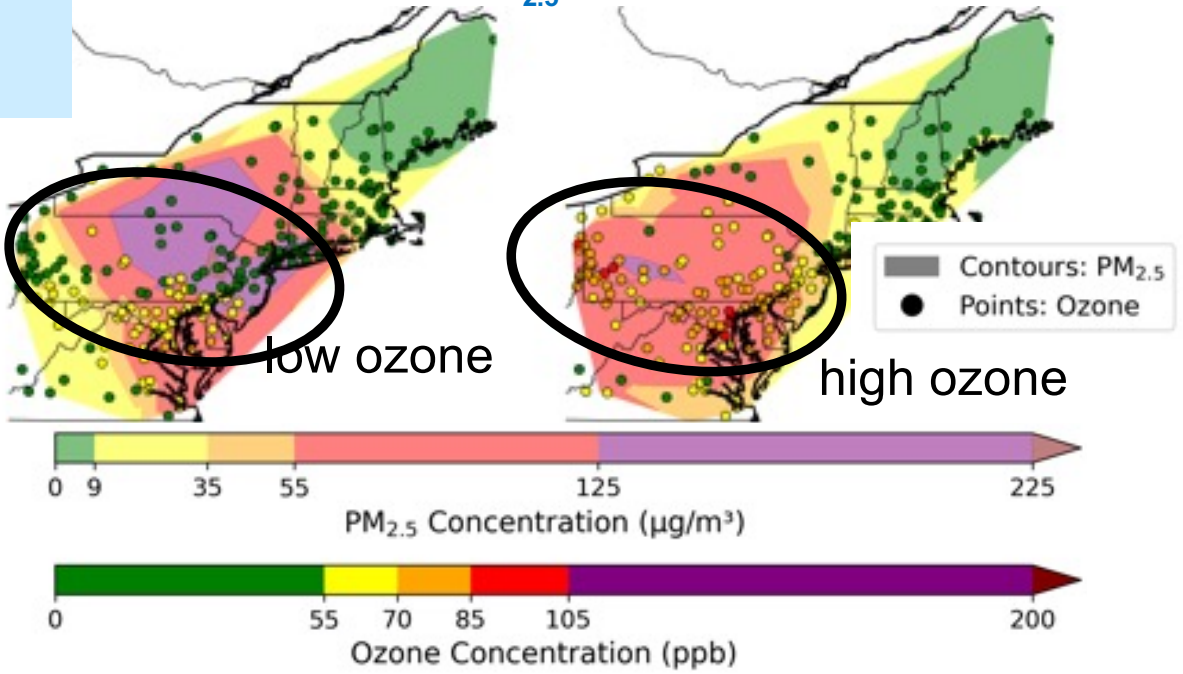
June 7, 2023 June 29, 2023



CrIS-JPSS1 PAN L2 FS, c/o S. Elkins (MIT)

State & local $PM_{2.5}$ & ozone monitors

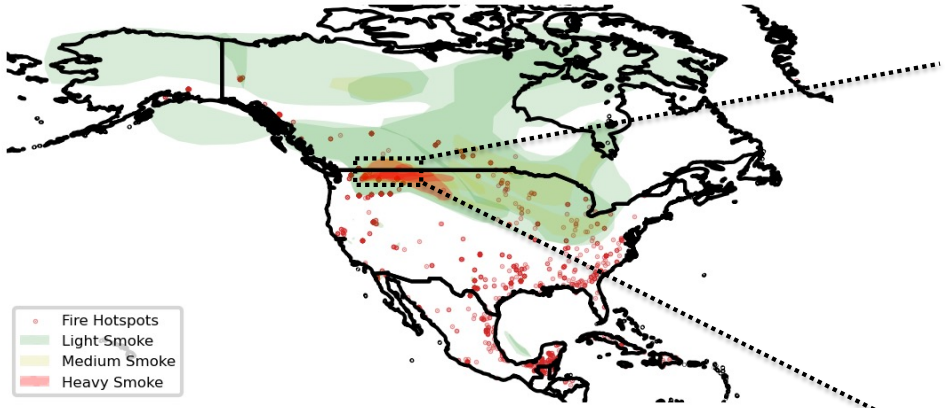


June 7, 2023: Canadian wildfire plumes hit NYC

Smoky haze covers New York City on Wednesday. COPYRIGHT 2023 THE ASSOCIATED PRESS. ALL RIGHTS RESERVED

Work in progress

Approach: Leverage airborne measurements to infer in-plume photochemical conditions & develop mapping to satellite products to tap wide spatial coverage



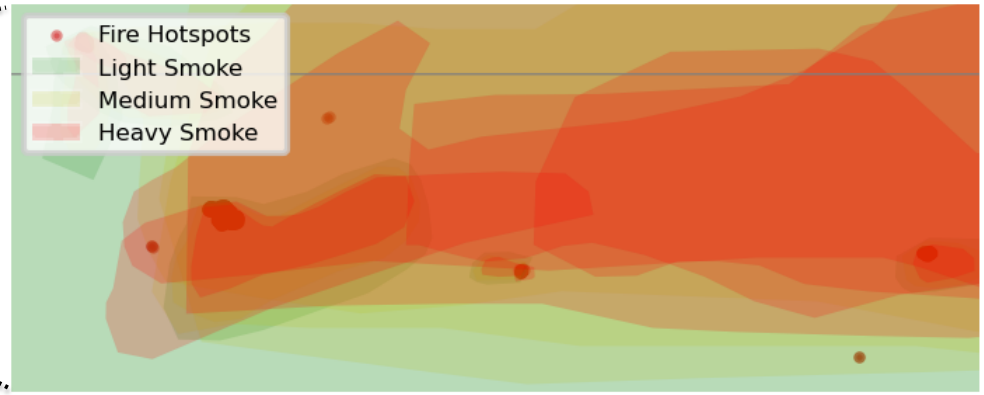
NASA; Wildfire Today

2019 case study: Williams Flats Fire (Washington)

FIREX-AQ

TROPOMI

August 8th, 2019



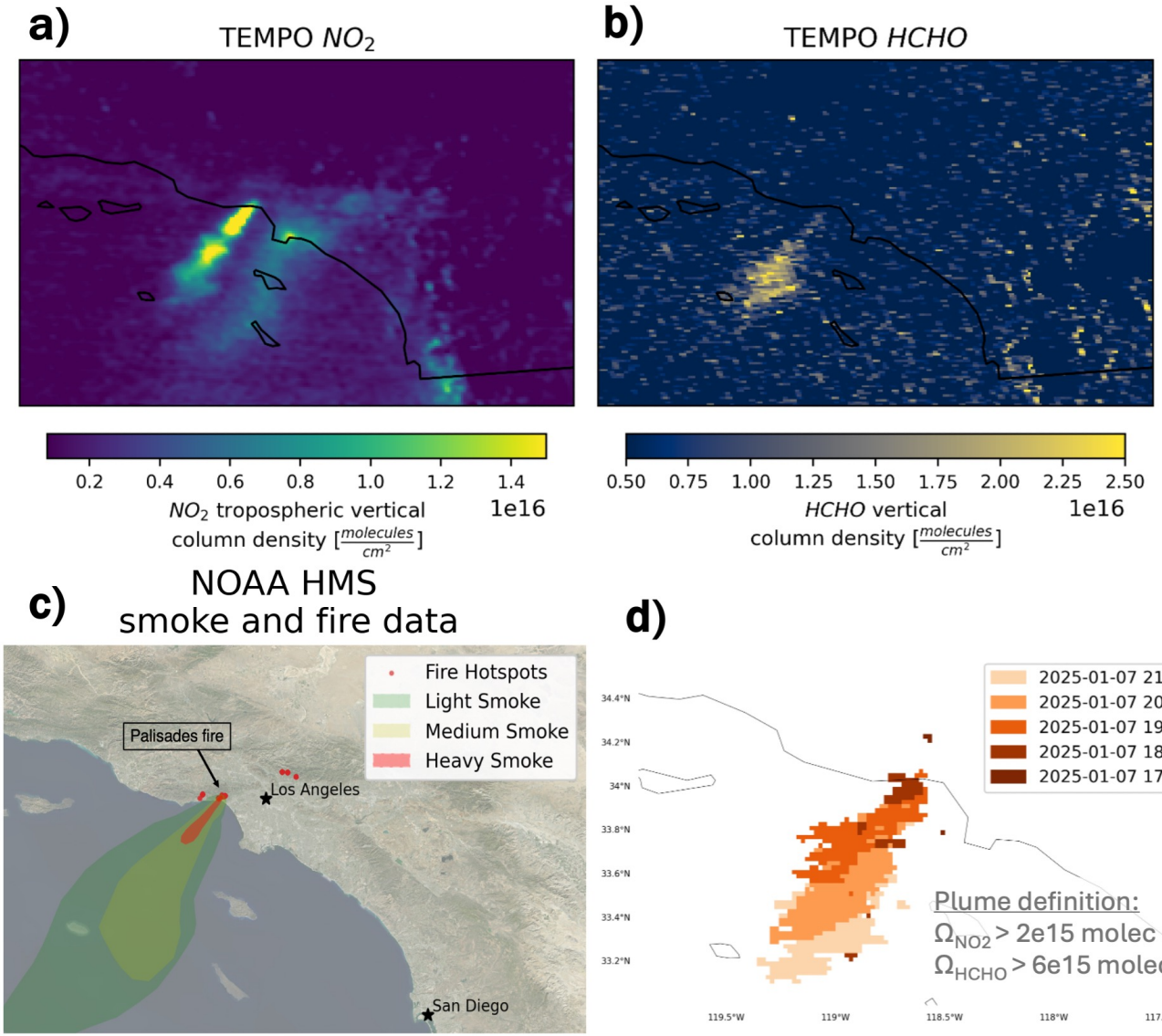
NOAA HMS

J. Palmo **Work in progress**

What new insights into ozone formation in fire plumes will TEMPO products reveal?

(Palisades fire, January 2025)

J. Palmo **Work in progress**

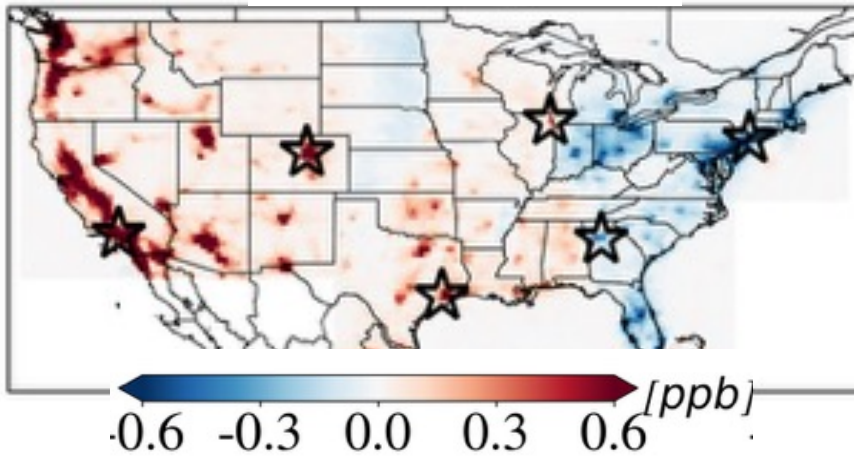


TEMPO-relevant finding: Monthly mean NO_2 abundances show spatially-varying sensitivity to the hourly timing of NO_x emissions

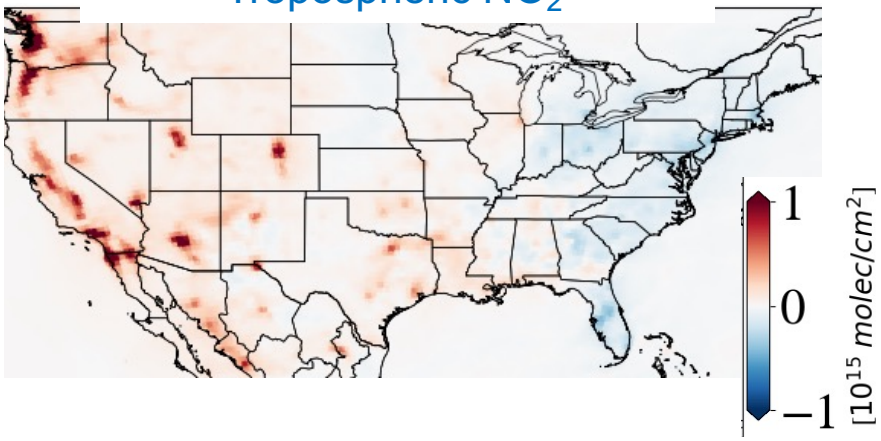
MUSICA-v0 chemistry transport model (14km resolution over the U.S.A.; ~100 km global)

Differences arising from use of hourly NO_x emissions rather than daily mean

SURFACE NO_2 (ppb)



VERTICAL COLUMN DENSITY
Tropospheric NO_2



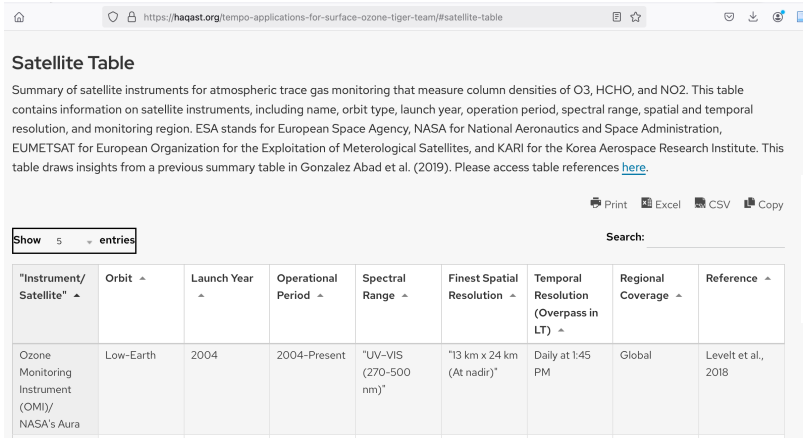
→ Implications for inferring NO_x emissions from space?

M. Tao et al., preprint in EGUSphere: https://doi.org/10.5194/egusphere-2025-4304

Interested to learn more about satellite products for ground-level ozone?
Please check out TEMPO-related HAQAST materials

https://haqast.org/tempo-applications-for-surface-ozone-tiger-team/

"Clickable" Table


https://haqast.org/tempo-applications-for-surface-ozone-tiger-team/#satellite-table

Satellite Table

Summary of satellite instruments for atmospheric trace gas monitoring that measure column densities of O3, HCHO, and NO2. This table contains information on satellite instruments, including name, orbit type, launch year, operation period, spectral range, spatial and temporal resolution, and monitoring region. ESA stands for European Space Agency, NASA for National Aeronautics and Space Administration, EUMETSAT for European Organization for the Exploitation of Meterological Satellites, and KARI for the Korea Aerospace Research Institute. This table draws insights from a previous summary table in Gonzalez Abad et al. (2019). Please access table references here.

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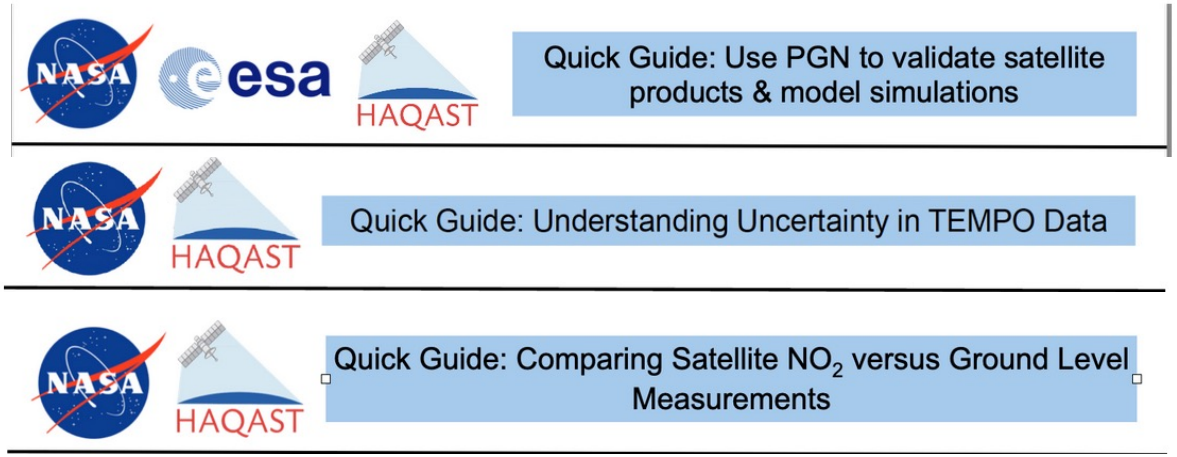
Show 5 entries Search:

"Instrument/ Satellite"	Orbit	Launch Year	Operational Period	Spectral Range	Finest Spatial Resolution	Temporal Resolution (Overpass in LT)	Regional Coverage	Reference
Ozone Monitoring Instrument (OMI)/ NASA's Aura	Low-Earth	2004	2004-Present	"UV-VIS (270-500 nm)"	"13 km x 24 km (At nadir)"	Daily at 1:45 PM	Global	Levelt et al., 2018

1-Page Plain Language Summaries



& Video Tutorials & Trainings Focused on TEMPO data

[produced by HAQAST3 TEMPO Applications for Surface Ozone Tiger Team]

Overarching questions guiding our HAQAST "Investigator Project"
& an introduction to our team

- *What controls "early-season" high-ozone events in the NEUS?*

  Kevin Civerolo
  Ruby Tian

  Alexandra Karambelas
  Paul Miller

- *What is the relationship between smoke and high-ozone events?*

  Temilayo Adeyeye

- *How does exposure to air pollution intersect with other cross-sectoral risk factors regionally and globally and how are these risks co-evolving over time?* [Co-I Adam Schlosser (MIT) presented this morning]

  Rohini Sampoornam Swaminathan
  Pallavi Pant

Technical collaborators:

Xiong Liu
Gonzalo González Abad
Caroline Nowlan

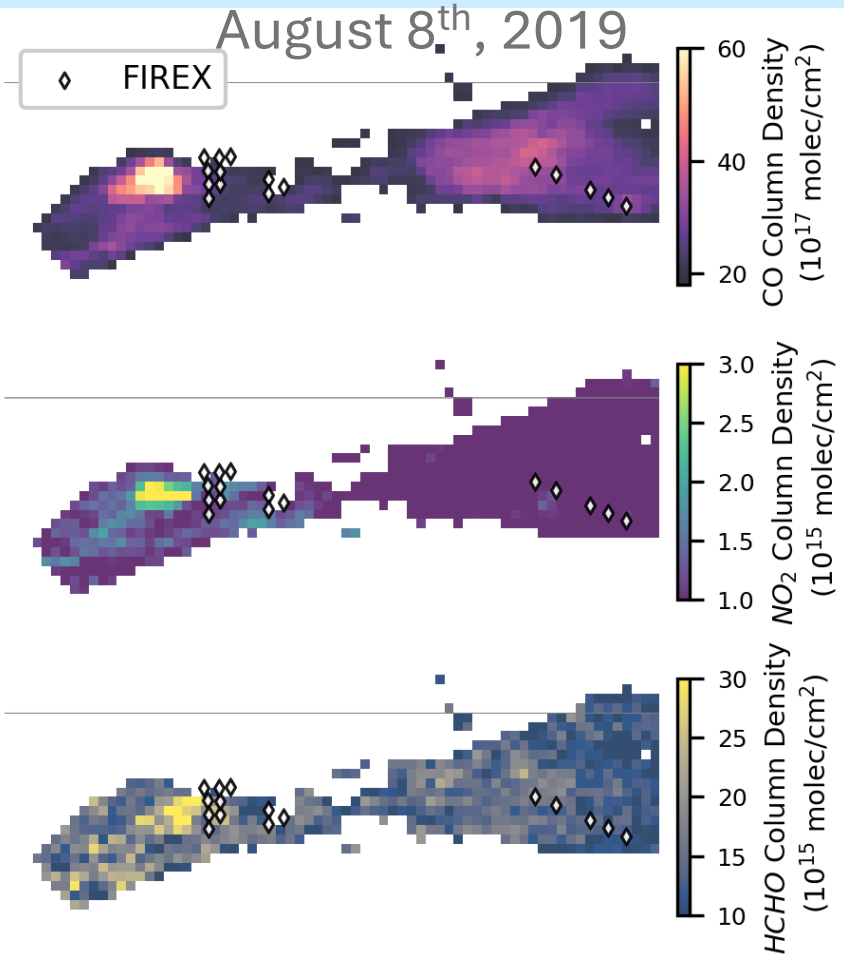
Xiaomeng Jin
Alex de Sherbinin

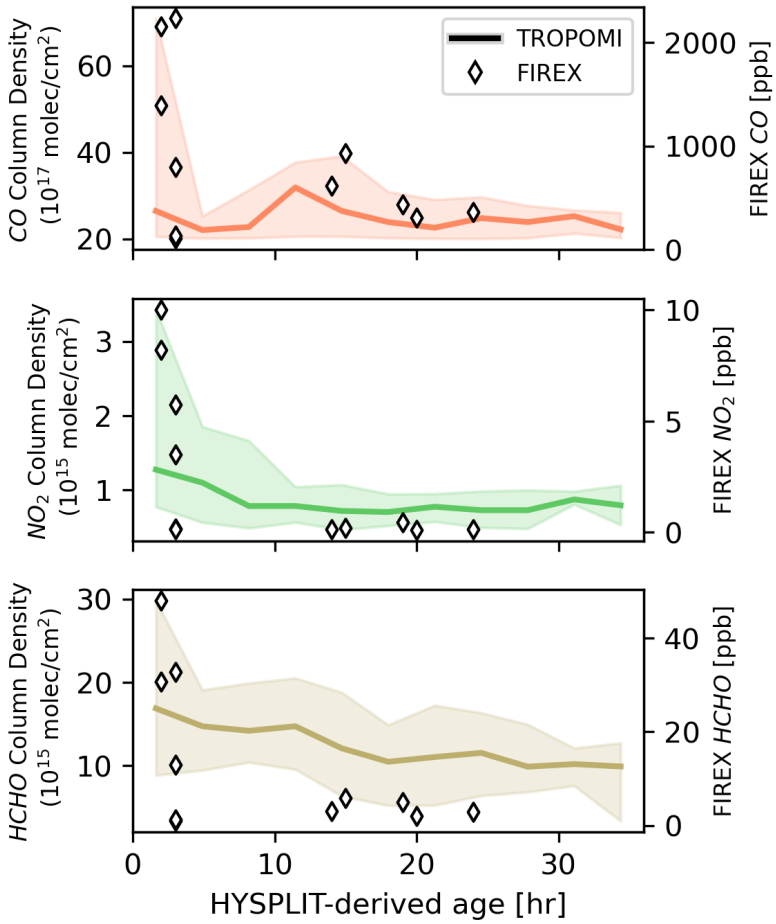
Marianthi-Anna Kioumourtzoglou
Lukas Valin


Joe Palmo

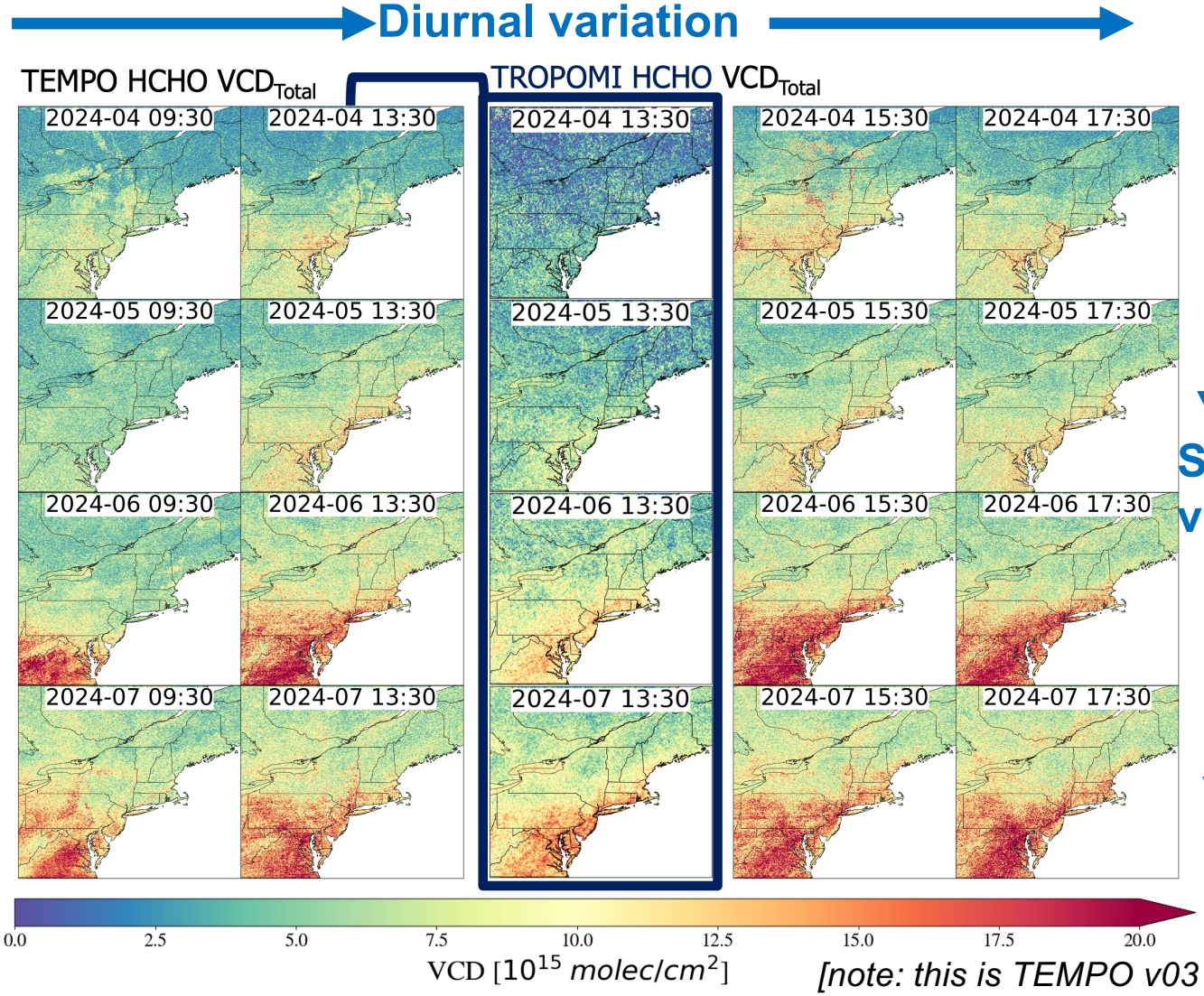

Madankui Tao

Preliminary FIREX-AQ versus TROPOMI shows promise for mapping plume-level chemistry; extension to other plumes is in progress





J. Palmo



In 2024, we have routine hourly formaldehyde (and tropospheric NO_2) vertical column densities streaming in from TEMPO during daylight hours

Seasonal variation

Madankui Tao (MIT)
Work in progress

[note: this is TEMPO v03 data; will update to v04 once processed]

We now have three decades of satellite data for air quality to connect ground-level ozone to local ozone-forming conditions

Figure c/o M. Tao; Harmonized GOME-SCIAMACHY-OMI-TROPOMI dataset c/o X. Jin Data + HCHO/NO_2 thresholds from Tian, Wang & Jin, EGUSphere, 2025