LADCO | LAKE MICHIGAN AIR DIRECTORS CONSORTIUM

Update on the 2023 AGES+ Field Campaign over Chicago

Angie Dickens

LADCO Data Scientist

LADCO Business Meeting
September 26, 2024

Overview of AGES+ Field Campaign

- Two major airborne field campaigns conducted flights over Chicago and Lake Michigan during August 2023 including:
  - NOAA's Atmospheric Emissions and Reactions Observed from Megacities to Marine Areas (AEROMMA)
    - Involves dozens of teams of scientists from many institutions
  - NASA's Synergistic TEMPO Air Quality Science (STAQS)
- LADCO helped organize additional ground-based assets in the Chicago area
  - With Brad Pierce (UW-Madison) & others
- Shorthand for whole campaign: AGES

  = AEROMMA/CUPiDS, GOTHAAM, ESCAPE, & STAQS

4415 West Harrison St., Suite 548
Hillside, IL 60162

Overall Goals

- AEROMMA (NOAA): Better understand current urban emissions & chemical formation of major air pollutants (e.g., ozone and aerosols)
  - Determine why concentrations are stabilizing
  - Particular focus on VOCs, especially from personal care products

https://chicago.suntimes.com/2023/8/1/23816372/nasa-aircraft-flies-low-over-chicago-nw-indiana-collecting-air-quality-data

Had over 30 individual instruments for gas-phase compounds, aerosols, and meteorological parameters

→ Detailed chemical and meteorological analyses

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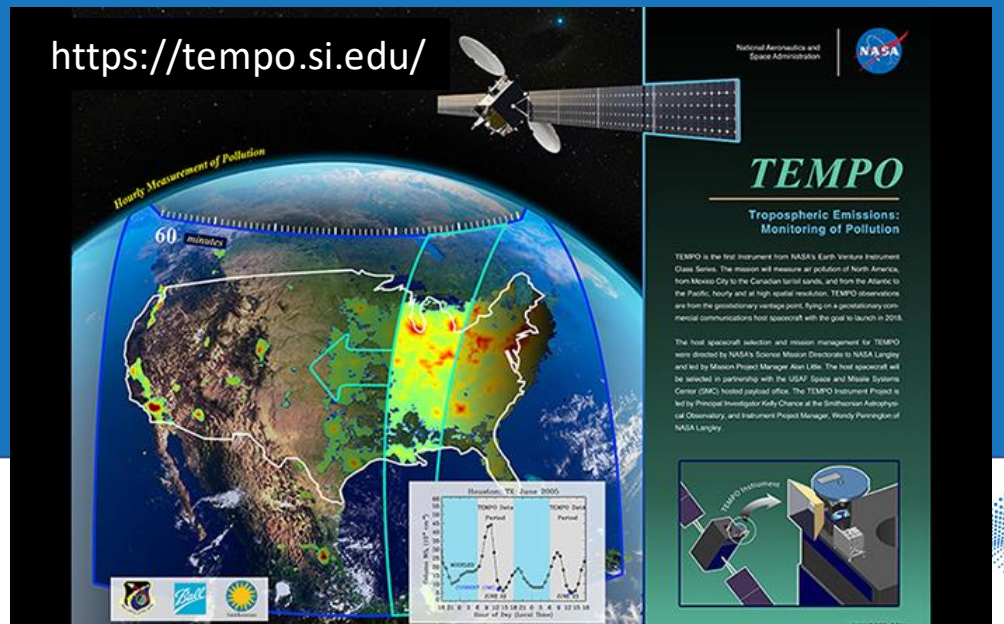
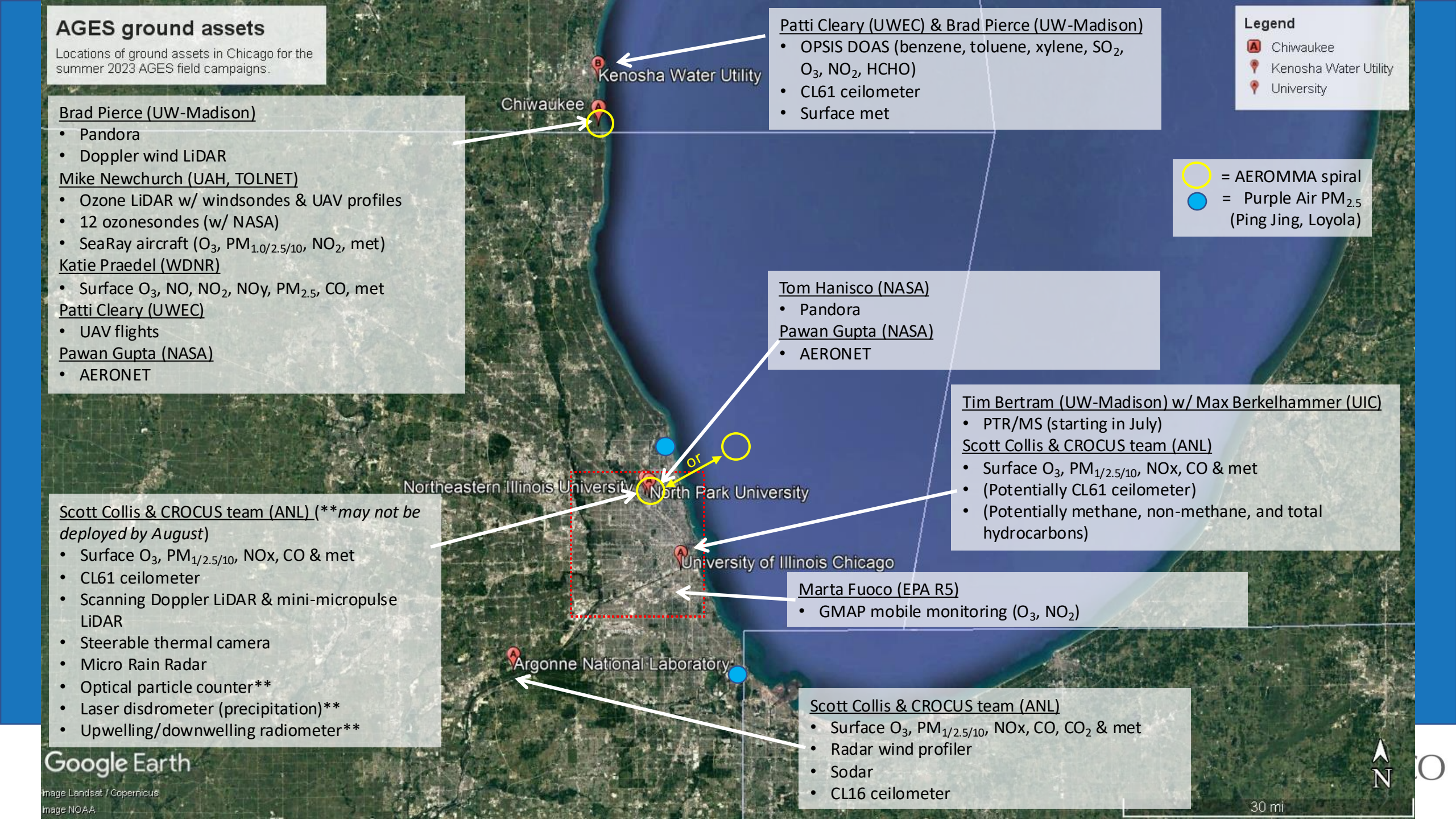
Overall Goals

- STAQS (NASA): Integrate new TEMPO satellite observations with traditional and enhanced air quality monitoring
  - Evaluate and improve TEMPO products
  - Interpret air quality events tracked by TEMPO
  - Improve emissions estimates

https://lvis.gsfc.nasa.gov/Home/Platforms.html

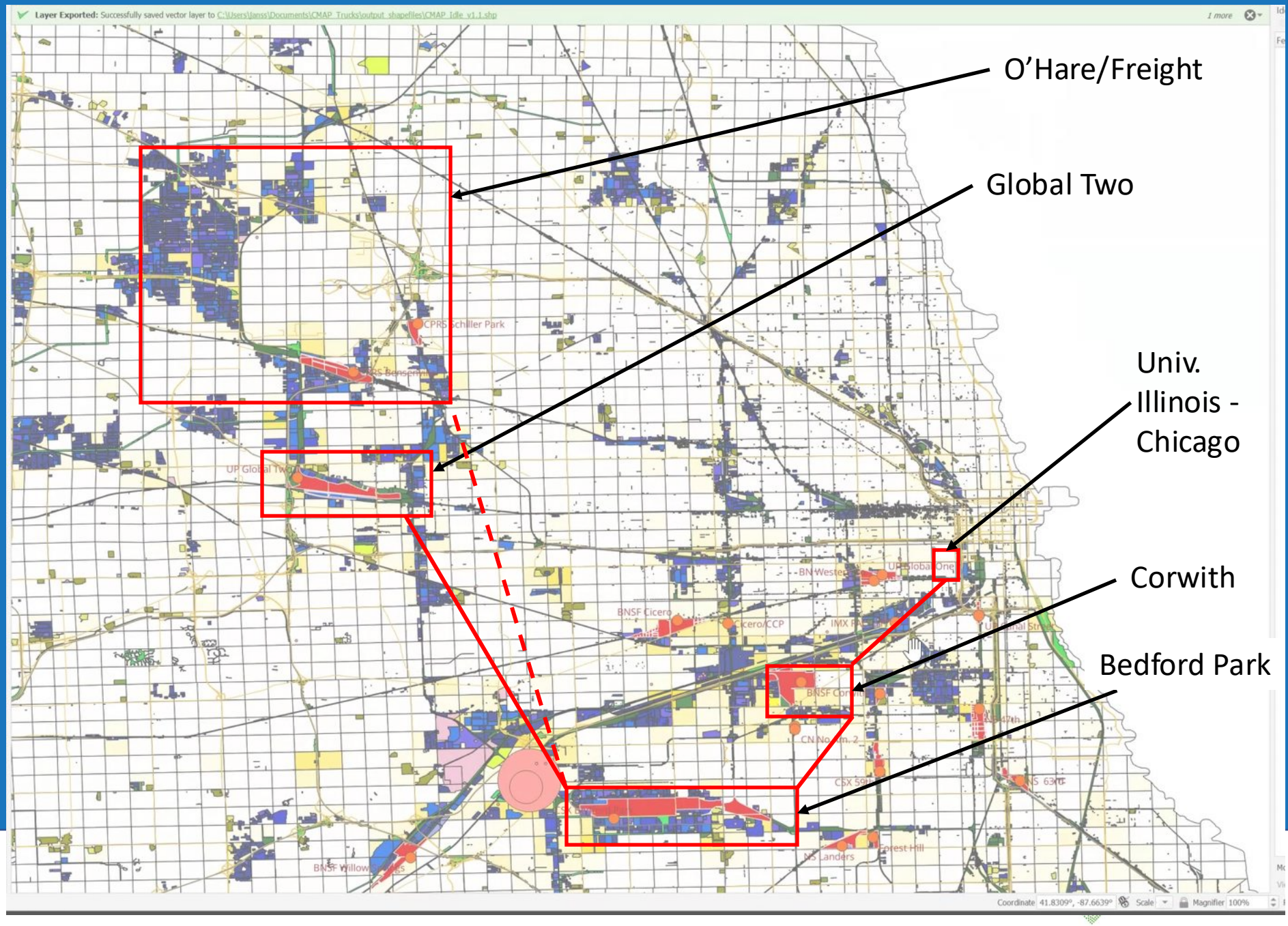



AGES ground assets
Locations of ground assets in Chicago for the summer 2023 AGES field campaigns.
Legend
Chiwaukee
Kenosha Water Utility
University
Patti Cleary (UWEC) & Brad Pierce (UW-Madison)
• OPSIS DOAS (benzene, toluene, xylene, SO_2, O_3, NO_2, HCHO)
• CL61 ceilometer
• Surface met
Kenosha Water Utility
Chiwaukee
Brad Pierce (UW-Madison)
• Pandora
• Doppler wind LiDAR
Mike Newchurch (UAH, TOLNET)
• Ozone LiDAR w/ windsondes & UAV profiles
• 12 ozonesondes (w/ NASA)
• SeaRay aircraft (O_3, $PM_{1.0/2.5/10}$, NO_2, met)
Katie Praedel (WDNR)
• Surface O_3, NO, NO_2, NOy, $PM_{2.5}$, CO, met
Patti Cleary (UWEC)
• UAV flights
Pawan Gupta (NASA)
• AERONET
= AEROMMA spiral
= Purple Air $PM_{2.5}$ (Ping Jing, Loyola)
Tom Hanisco (NASA)
• Pandora
Pawan Gupta (NASA)
• AERONET
or
Northeastern Illinois University
North Park University
Tim Bertram (UW-Madison) w/ Max Berkelhammer (UIC)
• PTR/MS (starting in July)
Scott Collis & CROCUS team (ANL)
• Surface O_3, $PM_{1/2.5/10}$, NOx, CO & met
• (Potentially CL61 ceilometer)
• (Potentially methane, non-methane, and total hydrocarbons)
Scott Collis & CROCUS team (ANL) (**may not be deployed by August)
• Surface O_3, $PM_{1/2.5/10}$, NOx, CO & met
• CL61 ceilometer
• Scanning Doppler LiDAR & mini-micropulse LiDAR
• Steerable thermal camera
• Micro Rain Radar
• Optical particle counter**
• Laser disdrometer (precipitation)**
• Upwelling/downwelling radiometer**
University of Illinois Chicago
Marta Fuoco (EPA R5)
• GMAP mobile monitoring (O_3, NO_2)
Argonne National Laboratory
Scott Collis & CROCUS team (ANL)
• Surface O_3, $PM_{1/2.5/10}$, NOx, CO, CO_2 & met
• Radar wind profiler
• Sodar
• CL16 ceilometer
Google Earth
Image Landsat / Copernicus
Image NOAA
N
30 mi

EPA R5 GMAP Routes

- Driven 4 days (twice daily)
- Timed to coincide with STAQS flights
- Measuring NO_2 ozone

- LADCO hired a summer intern to analyze data



The campaign went wonderfully!

- AEROMMA/STAQS planned on 4 flight days over Chicago. Did 5 flight days!
  - Including on TEMPO satellite "First Light" day
  - Also flew over Detroit & Indianapolis one day each
- University of Alabama – Huntsville (UAH) was based in Southeast WI:
  - Measured ozone profiles with LiDAR on 21 days
  - Measured ozone and NO_2 from a small plane on 41 flights on 19 days
  - Conducted 180 chemistry/meteorology profiles using drones on 16 days
  - Launched 12 ozone sondes and 65 windsondes (balloons)
- U.S. EPA Region 5 drove a mobile monitoring vehicle (GMAP) in Chicago on 4 flight days
- Extensive ongoing measurements on the ground by Argonne National Lab, UW-Madison, UWEC, and others (direct measurements & remote sensing)

Initial Results!

All results are preliminary and are likely to change with additional analysis

Slides are courtesy of the authors listed on them. Slides are mostly from the 2024 AGES+ Meeting or the 2023 AGES+ Chicago Data Workshop

Initial Results Topics

- STAQS
- AEROMMA
  - Aerosol composition
  - Smoke impacts
  - Ozone and OH chemistry
  - NH_3 emissions
- LMBREEZE (SE WI-based ground/aircraft study)
- Ground-based VOC measurement

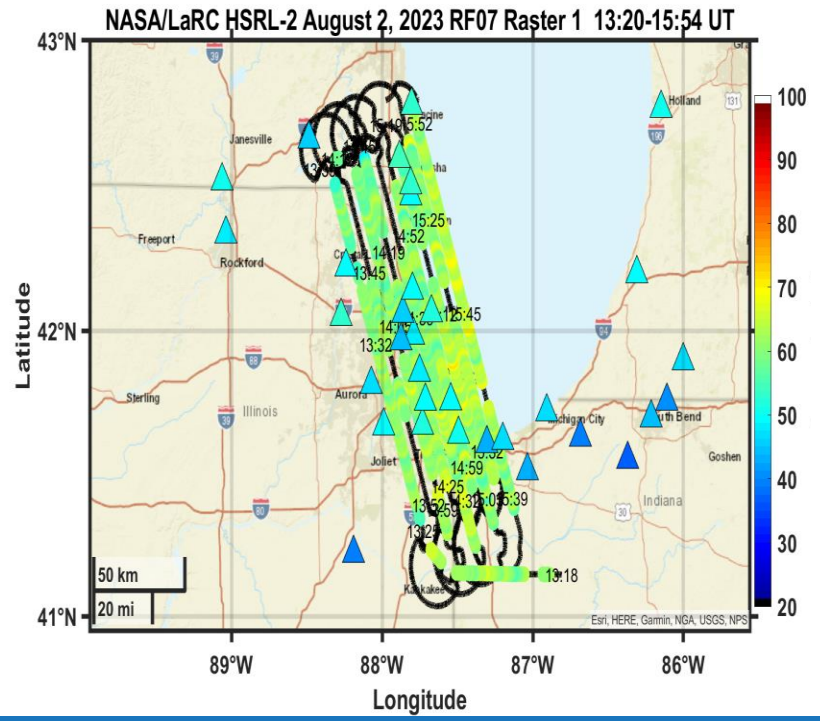
Laura Judd (NASA): STAQS Measurements

Chicago August 2, 2023—TEMPO First light

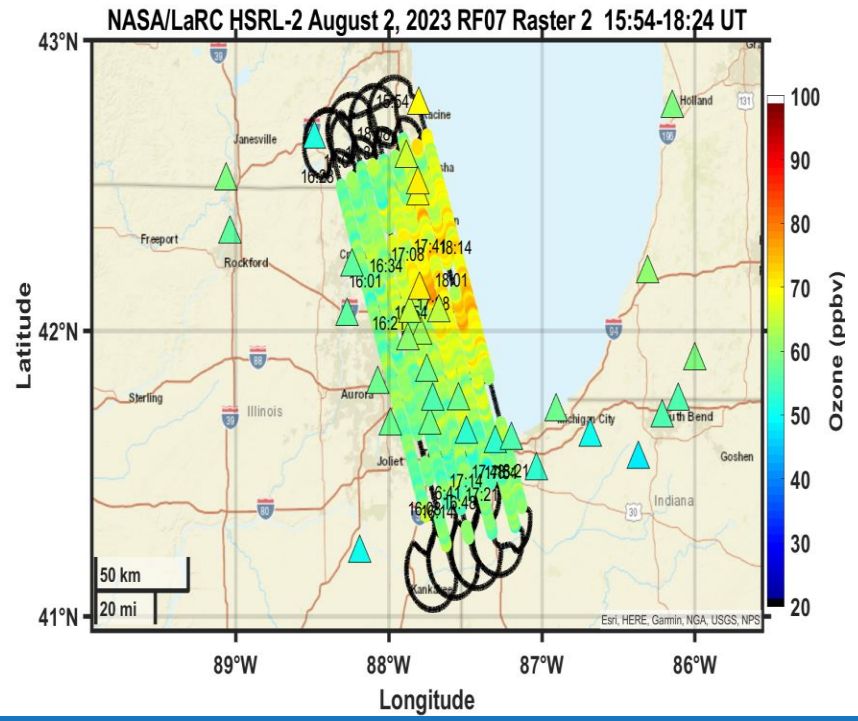
High Spectral Resolution Lidar-2

—NASA airborne capability for profiling ozone concentrations and aerosol properties

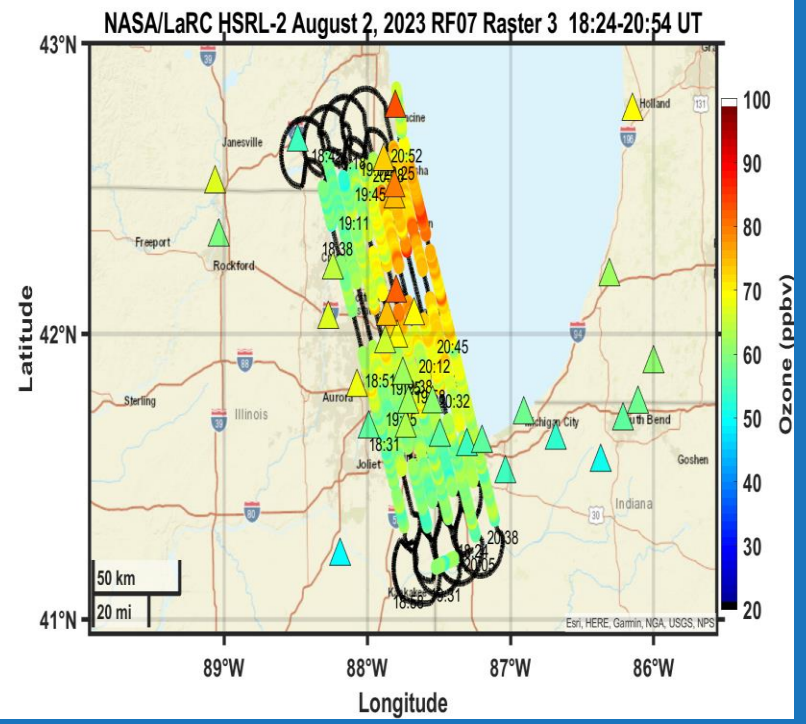
morning



midday



afternoon



Similar products will be available for mixing layer depth and near surface AOD

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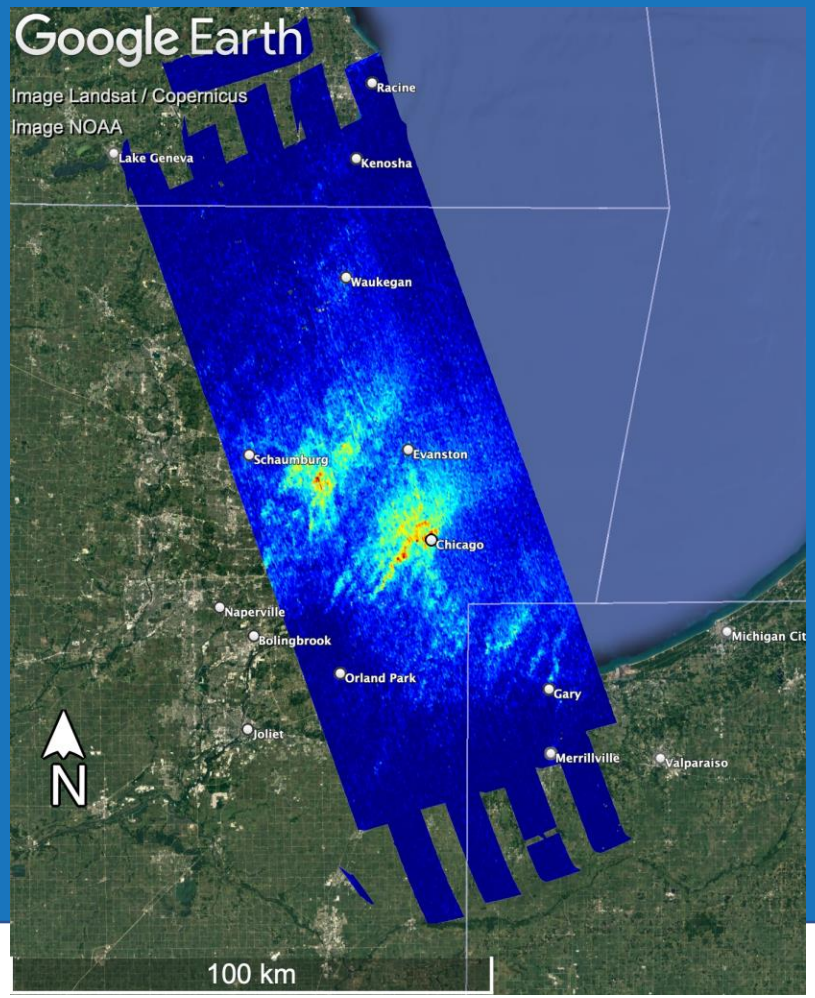
Slide courtesy of Laura Judd (NASA)

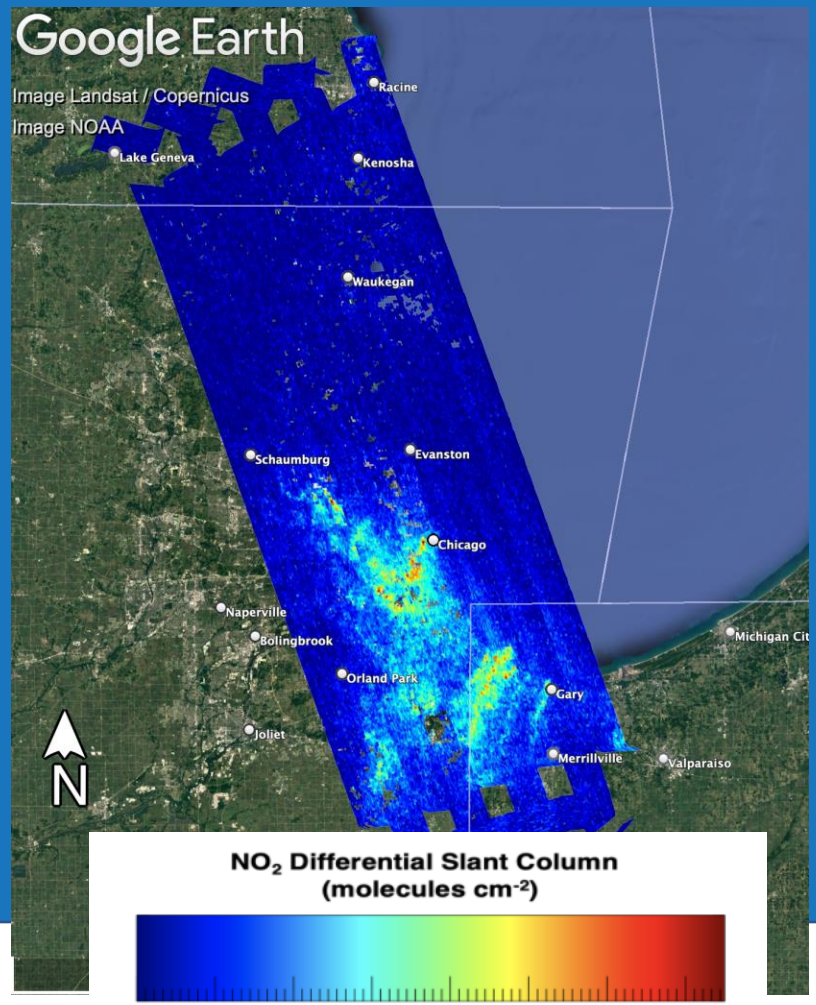
Laura Judd (NASA): STAQS Measurements

GCAS Midday Views

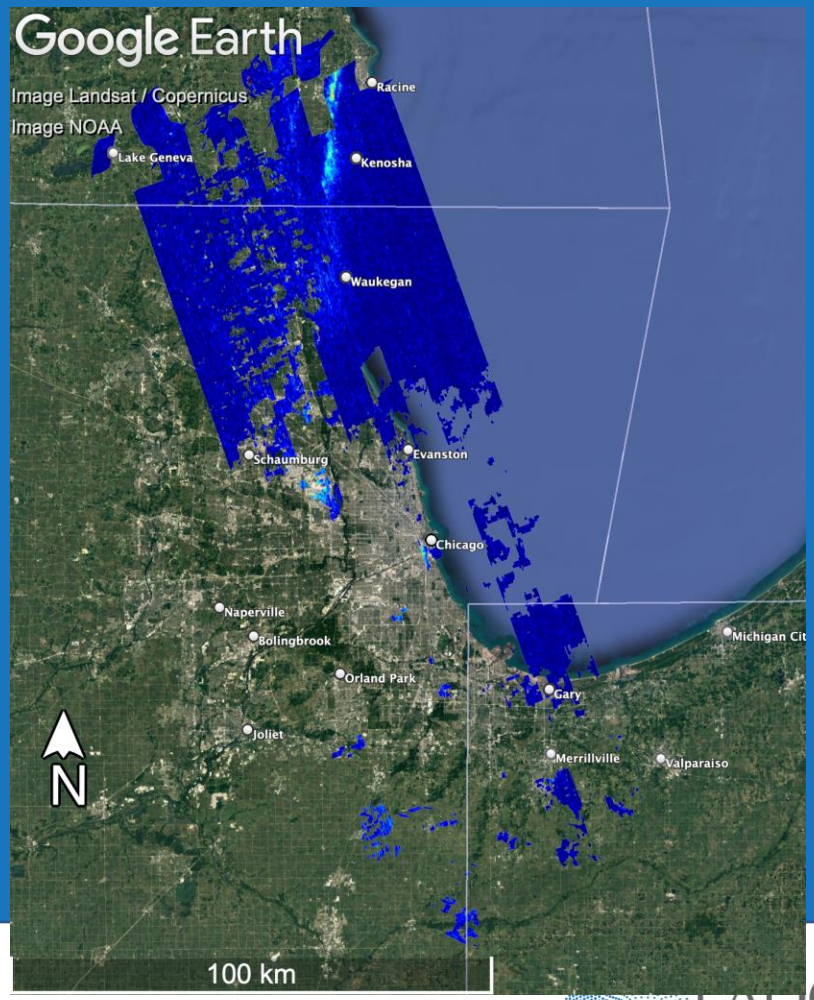
August 2nd



August 12th



August 15th



Slide courtesy of Laura Judd (NASA)

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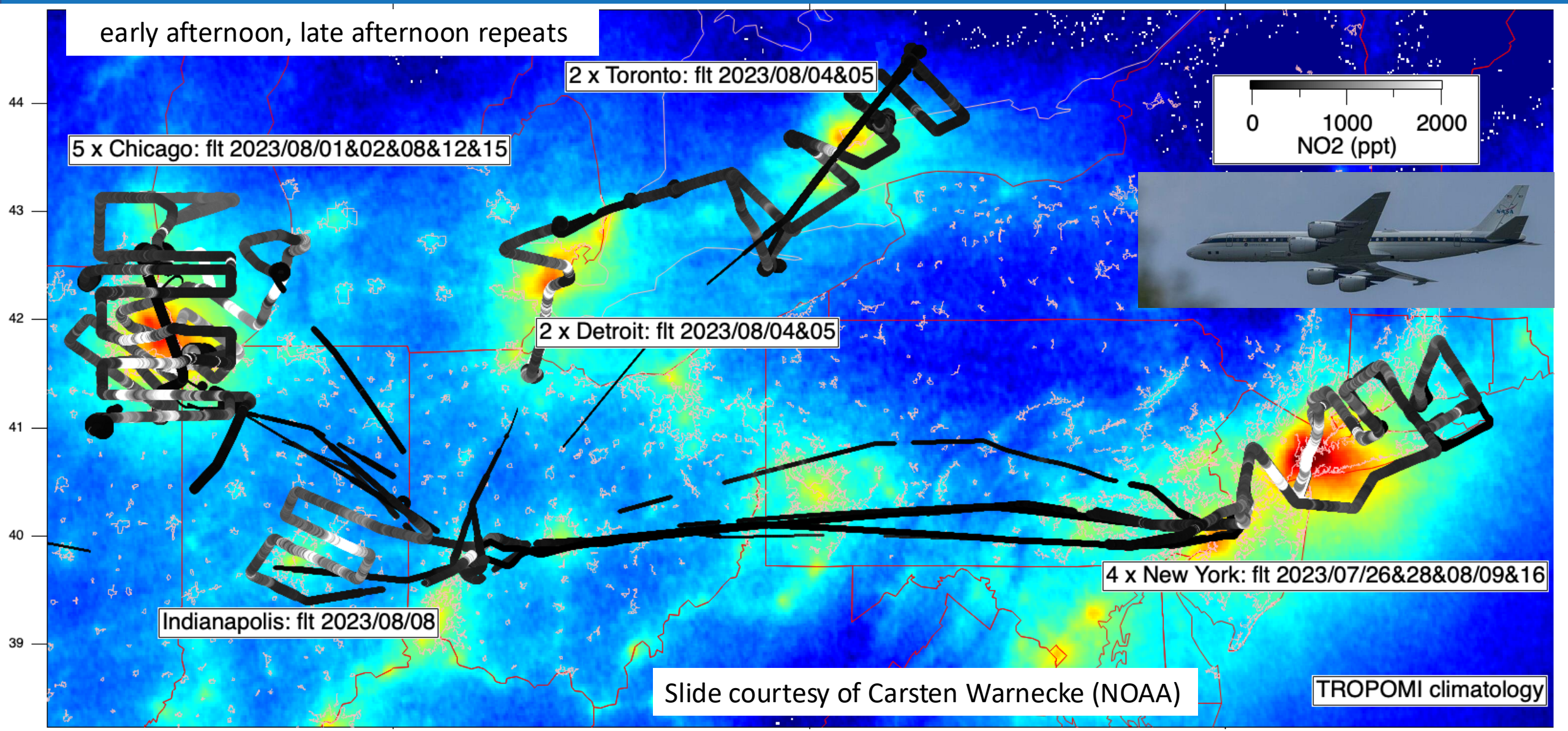
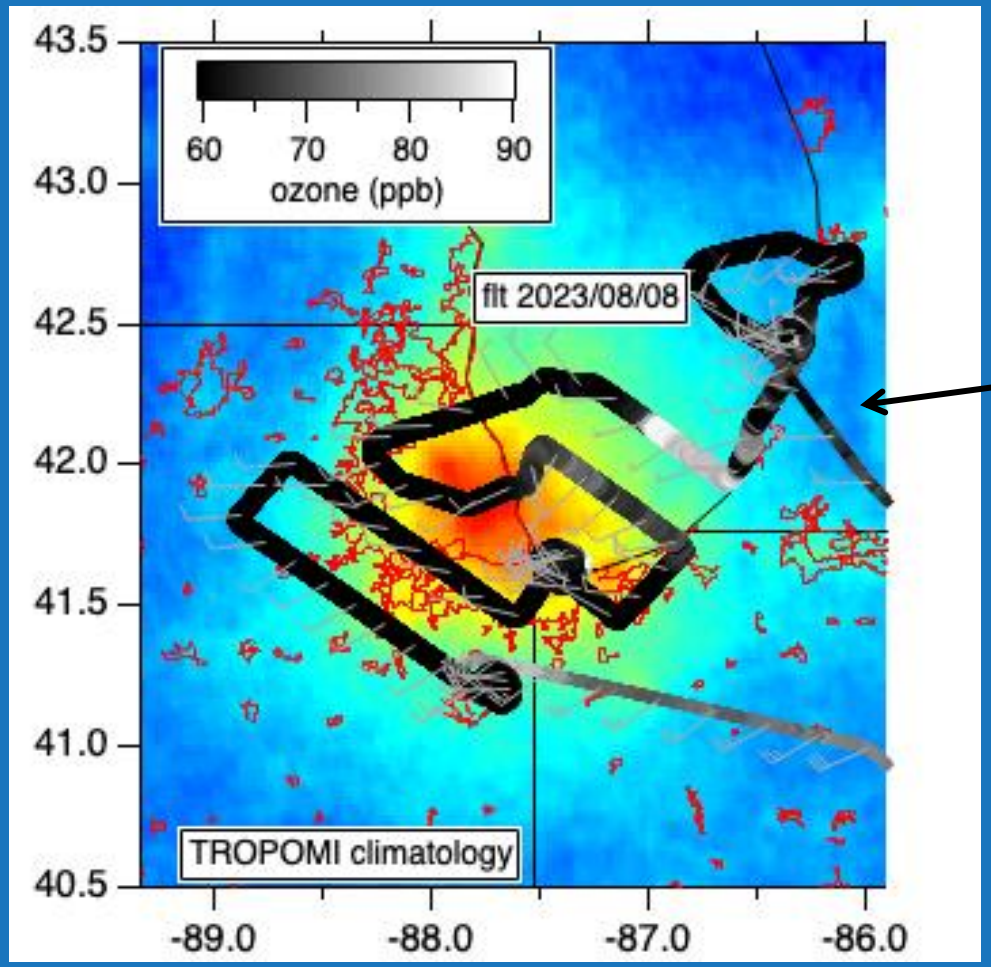
Carsten Warnecke (NOAA): AEROMMA flights (July-August)



Note: colored map is long-term average NO_2 from a satellite, not from the field campaign

Carsten Warnecke (NOAA): AEROMMA flights (July-August)

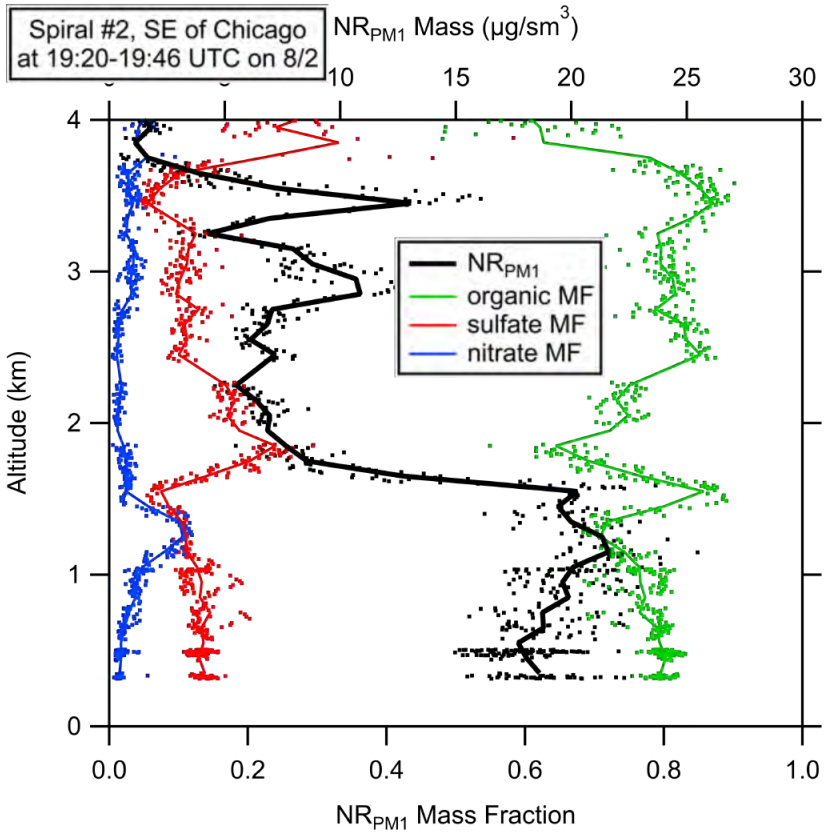


- 5 flight days
  - 2 focused on emissions measurements (NO_2)
  - 3 days focused on ozone formation and transport
- Took many detailed measurements of chemistry
  - Get at emissions sources and pollutant formation chemistry

Figure courtesy of Carsten Warnecke (NOAA)

Anne Middlebrook (NOAA): Aerosol chemical composition

Composition Often Varied with Altitude: Example of one up/down spiral



Above 3.75 km, composition has significant sulfate (red) and organic (green) mass fractions

Between ~2-3.5 km, two distinct layers of higher mass (black) with a high organic mass fraction (green)

Between ~1.5-2.5 km, sulfate mass fraction (red) is elevated

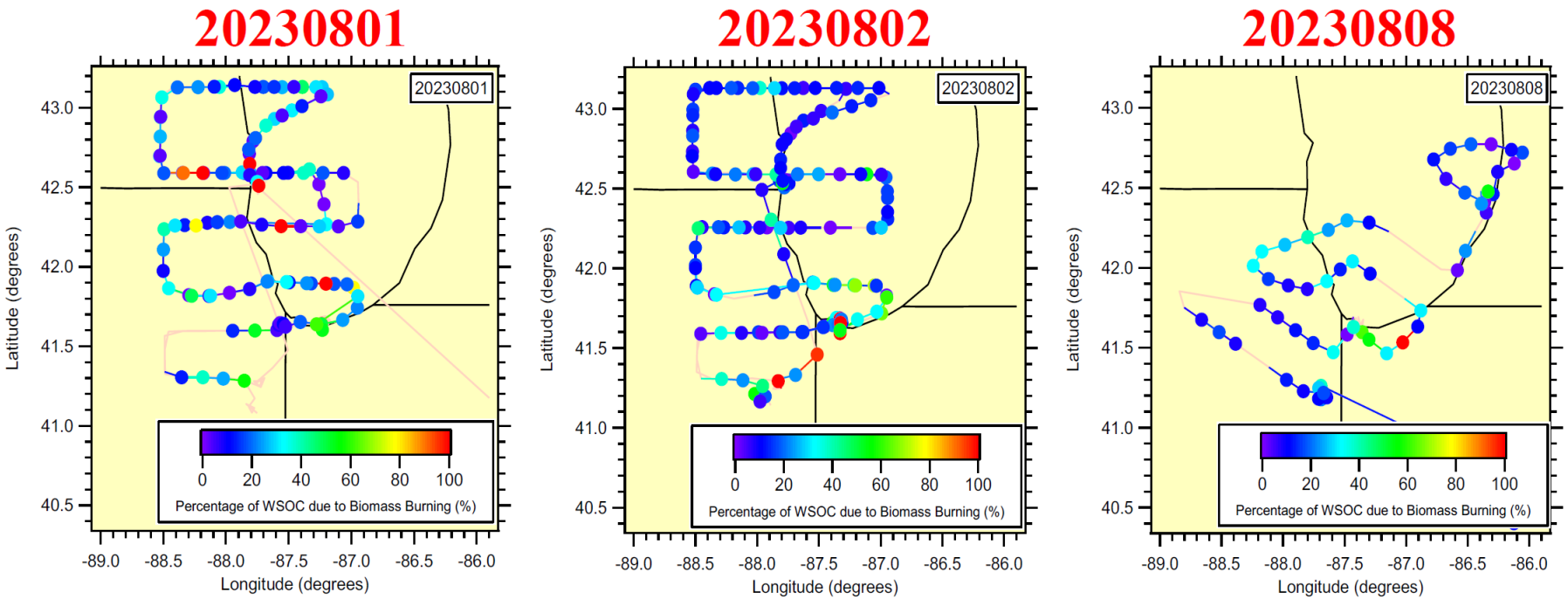
At ~1.25 km, nitrate mass fraction (blue) has a peak

Closest to the surface (less than 1 km), composition again has significant sulfate (red) and organic (green) mass fractions

Dots are individual points from ascent and descent; lines are averages of both.

Amy Sullivan (CSU): Aerosols & Biomass Burning

Percentage of WSOC due to Biomass Burning Chicago



WSOC = water-soluble organic carbon

Study uses levoglucosan as a marker of biomass burning

-Observe higher contributions for Aug. 1st flight, average ~30%
-Contribution on average ~20% for other Chicago flights

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Lu Xu (Wash U): Ozone in aged wildfire plumes

- During transport in the free troposphere, PAN converts to NO_3 (slowly)
- VOC reactivity in plumes is dominated by CO, HCHO, and CH_4 near the fires, with many more complex VOCs

Meiyun Lin (NOAA): Wildfire smoke impacts

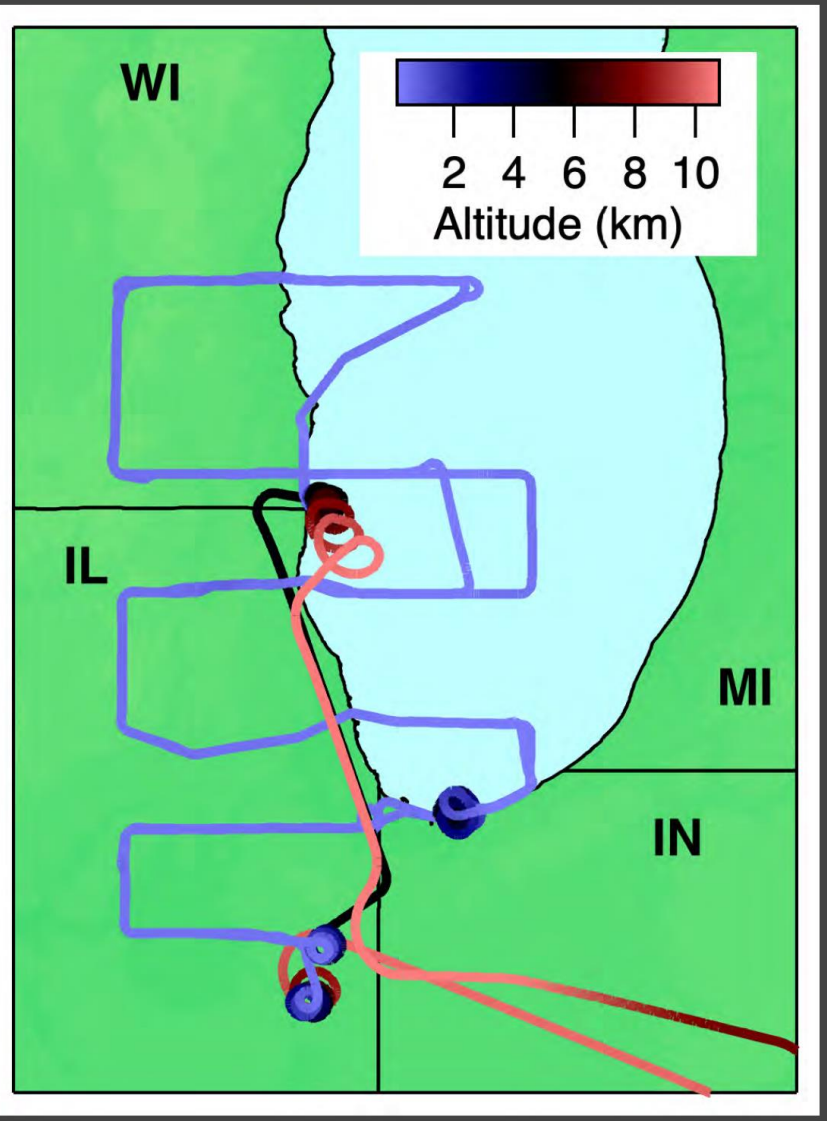
- Western U.S. based on a model
- NOy chemistry reduces ozone production in fresh smoke plumes (from a model)
- As PAN decomposes in the plume, it enhances ozone formation downwind away from the fire
- Get additional ozone as smoke VOCs mix with NOx in urban plumes

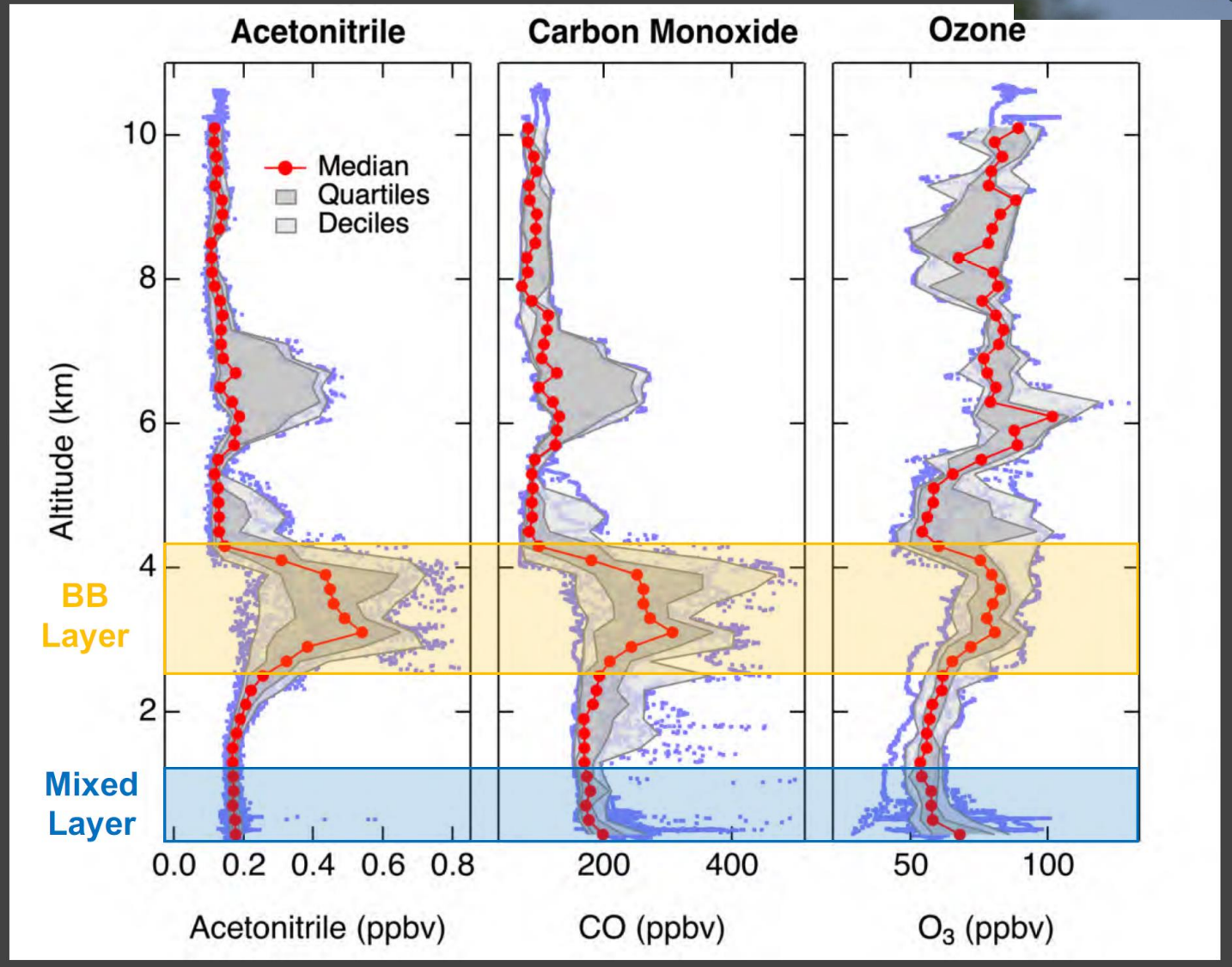
Matthew Davis (Univ. Toronto): Reactive N in Toronto

- Particulate amines (NHx) and NH_3 are elevated during heavy smoke periods
- But ground-level NH_3 wasn't high during extreme wildfire events in 2023

Steve Brown (NOAA): Ozone in biomass burning plumes

August 1 DC-8 Flight to Chicago





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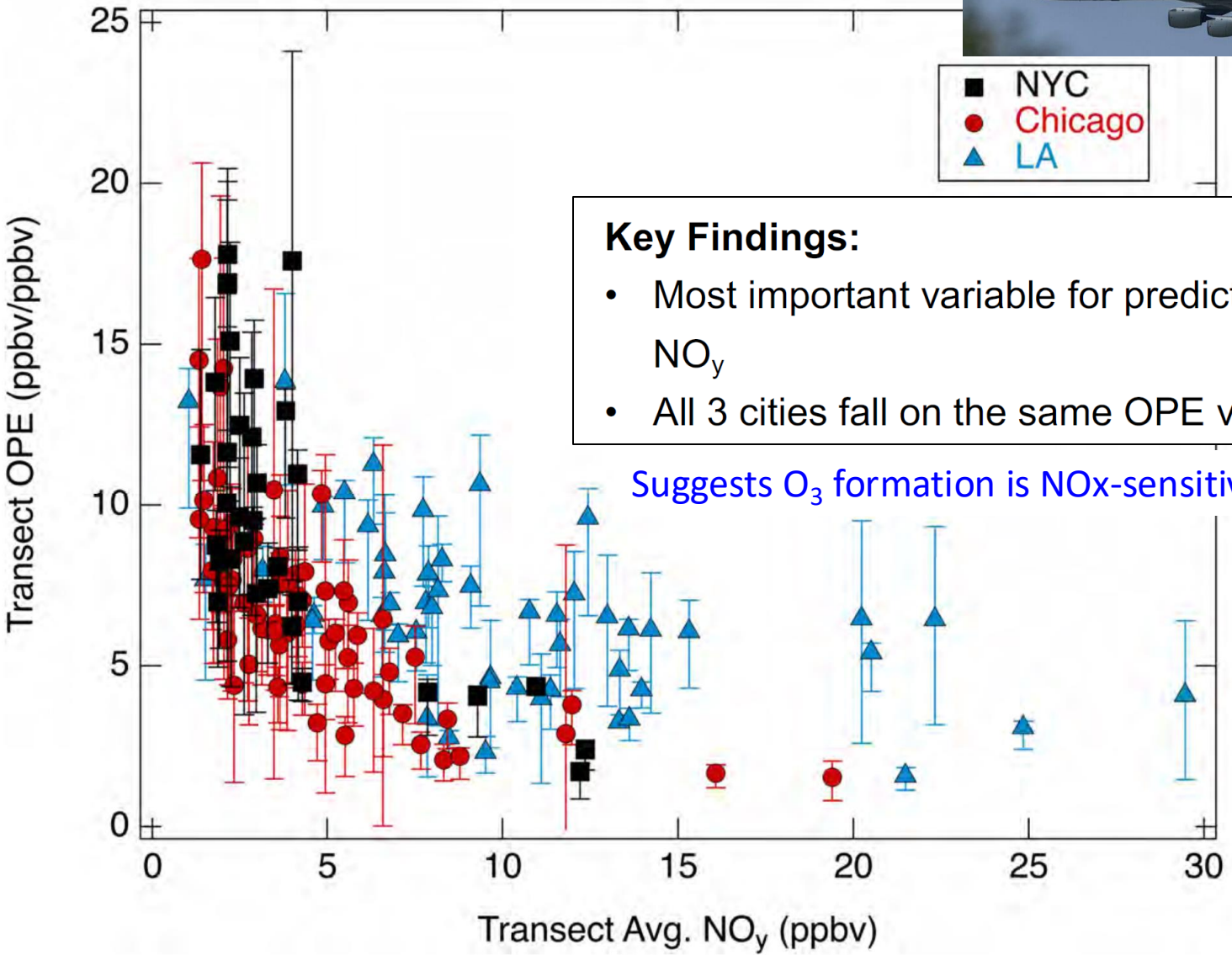
Wyndom Chase (NOAA): Ozone Production Efficiency (OPE)

OPE Dependence on NO_y

City	Avg. OPE (ppbv/ppbv)
NYC	10 ± 4
Chicago	7 ± 3
LA	7 ± 3

OPE vs NO_y

- OPE is anticorrelated with NO_y (≈ emitted NO_x)
- Consistent with trends in literature



Key Findings:

- Most important variable for predicting OPE is NO_y
- All 3 cities fall on the same OPE vs NO_y curve

Suggests O_3 formation is NOx-sensitive in all areas

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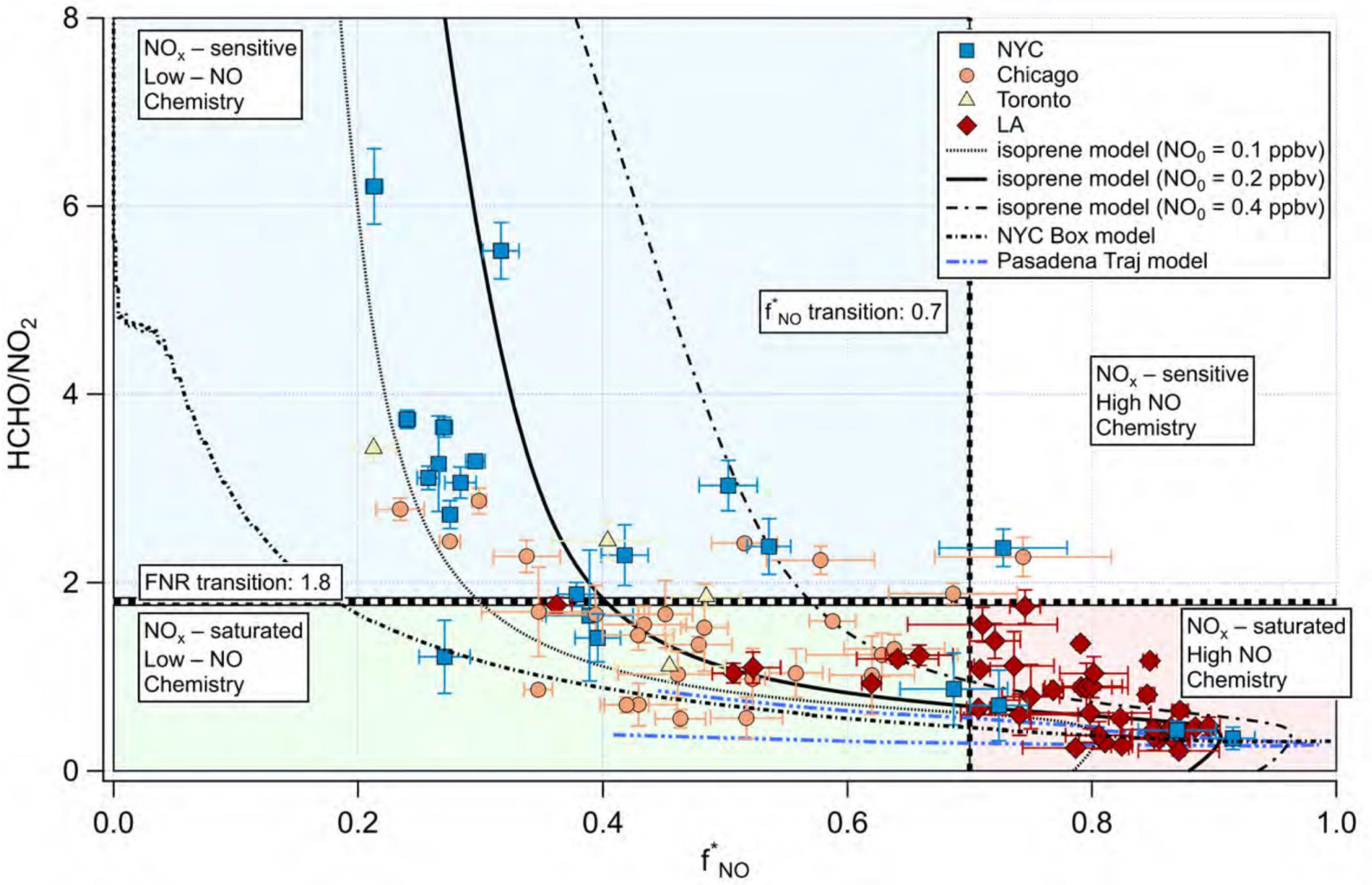
Mike Robinson (NOAA): Urban photochemical regimes



- As emissions decrease, move from red to green to blue boxes
- Chicago O_3 formation is mostly NOx-saturated (VOC-sensitive)
  - Also NOx-sensitive
  - With low-NO chemistry
- LA is more NOx-saturated
- NYC is less NOx-saturated

Coggon et al. 2021; Stockwell et al. 2024 *in prep*

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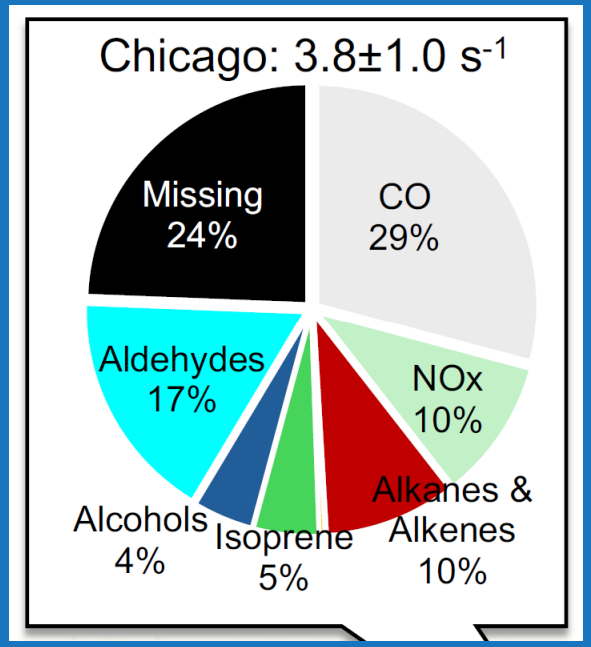
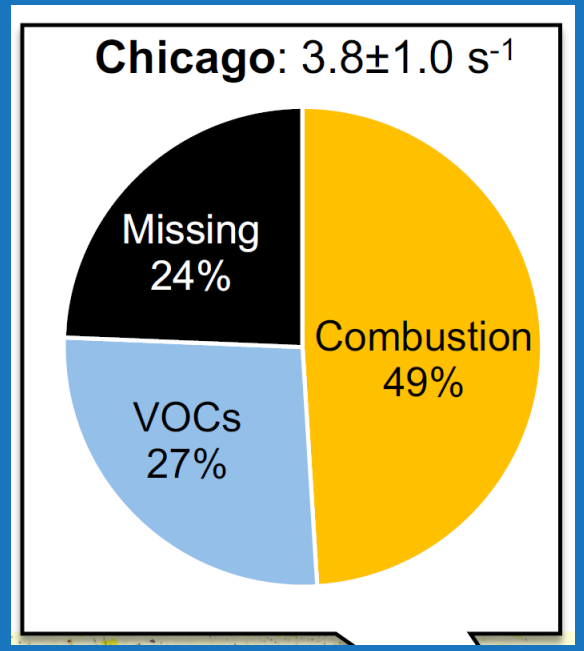
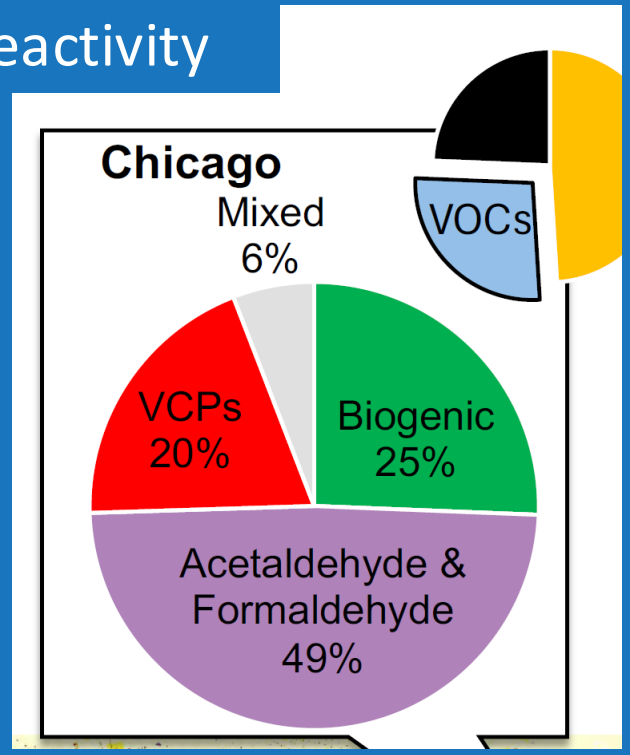
Aaron Stainsby (Forschungszentrum Jülich): OH Reactivity

Reactivity by species



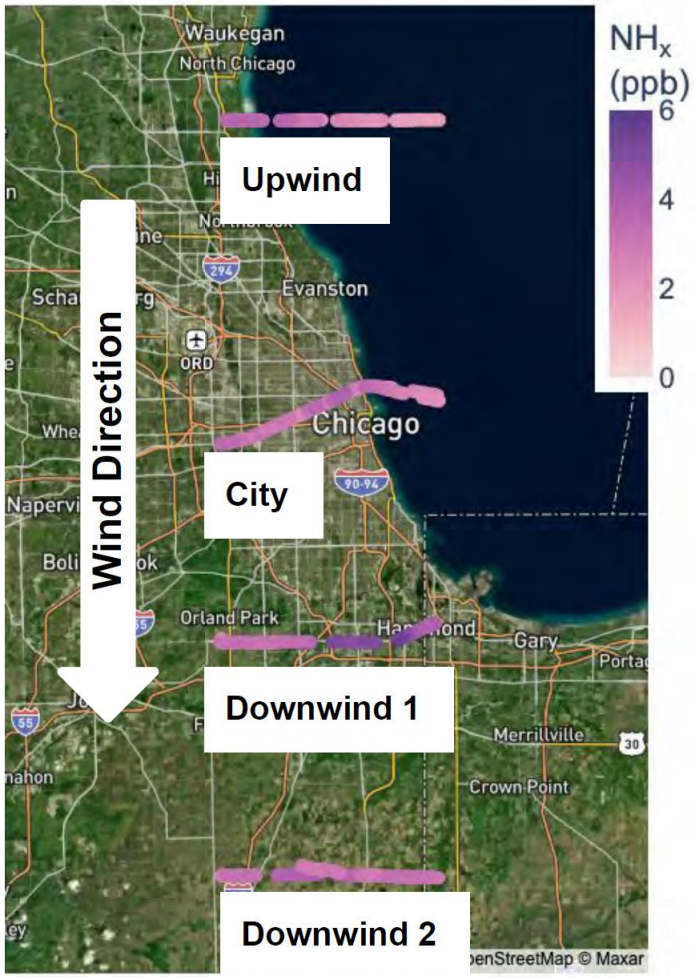
Source reactivity

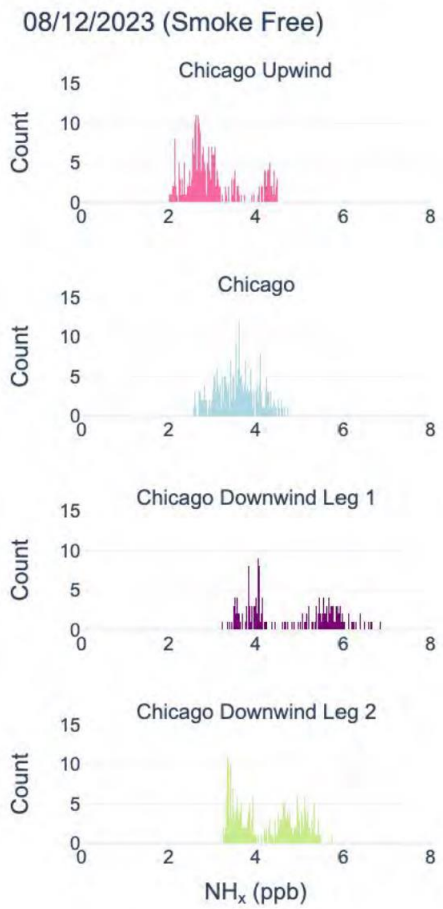




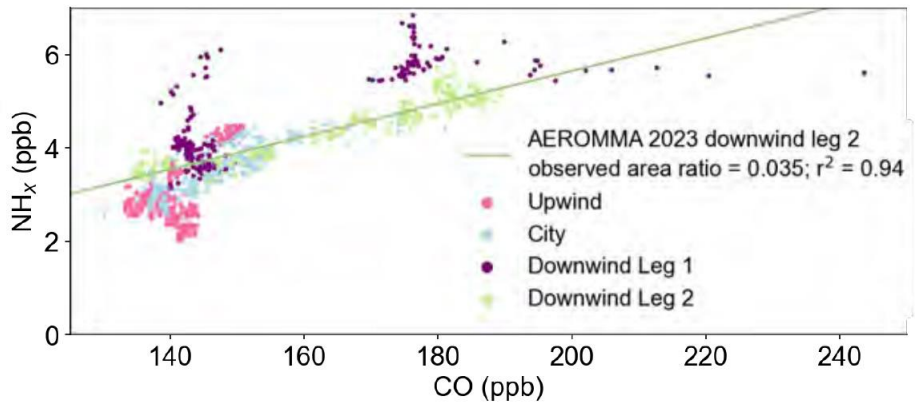
Emily Lill (Colorado State): Urban ammonia emissions

In Chicago, Strong NH_x:CO relationship downwind of the city suggests urban influence on ammonia mixing ratios downwind of the city.





Enhancement ratio associated with transects downwind of Chicago urban area



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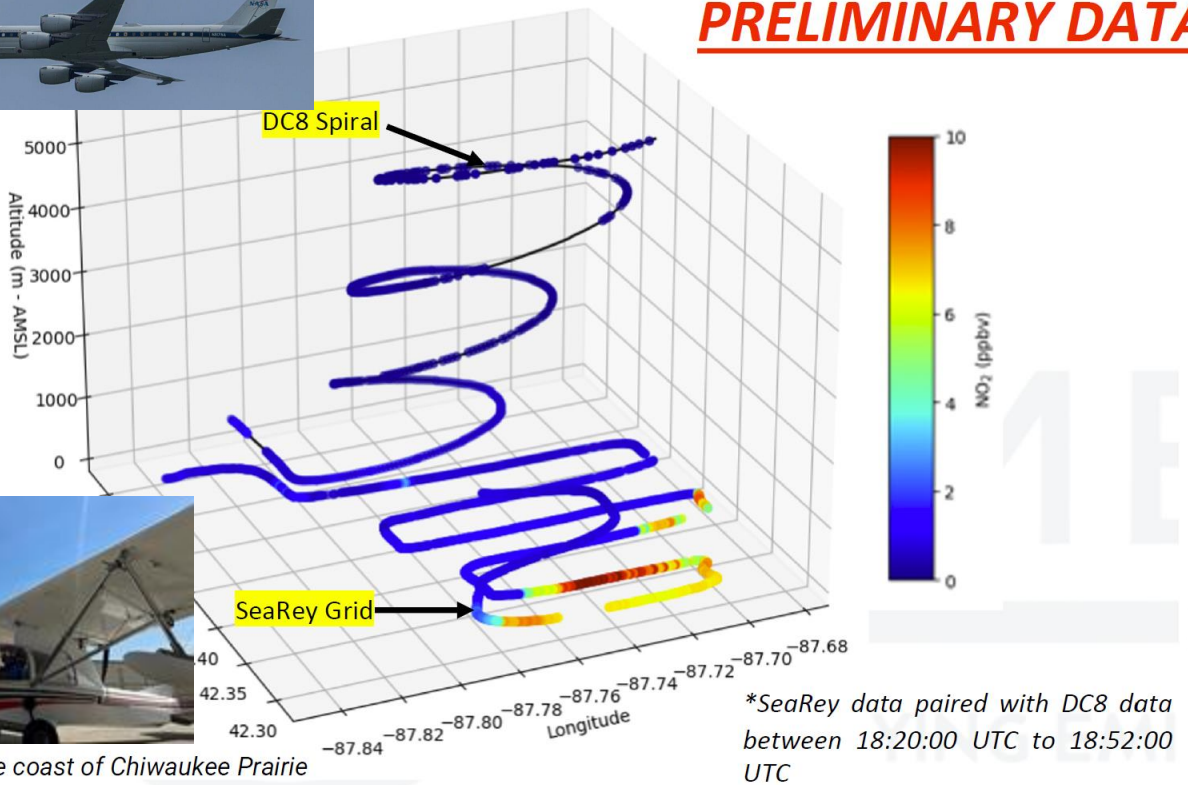
Mike Newchurch (UAH): LMBreeze campaign, at Chiwaukee

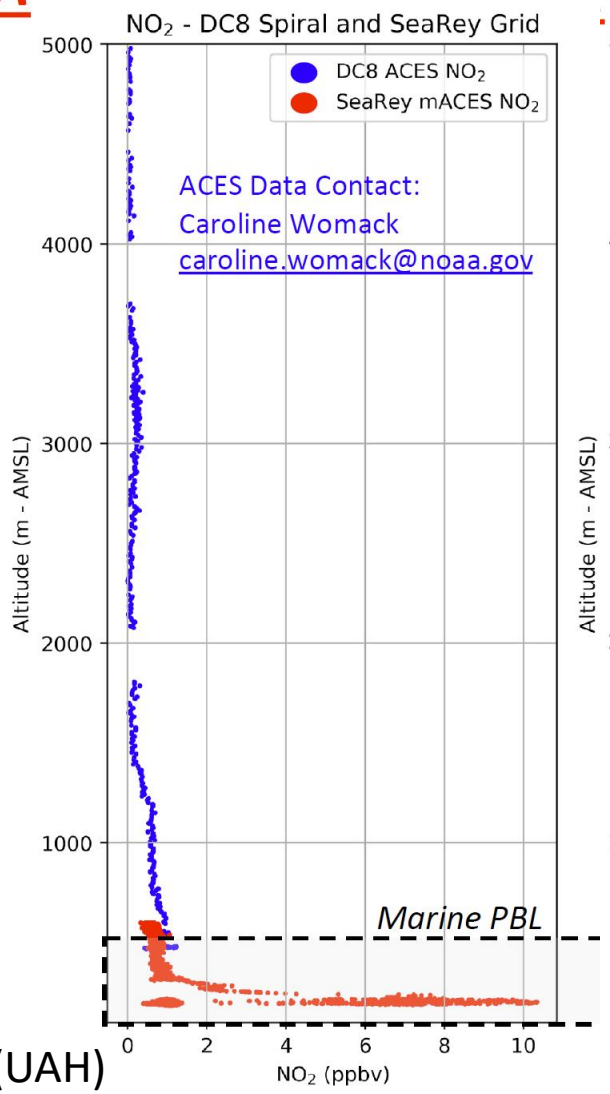
August 1, 2023 – SeaRey vs. DC-8 NO_2 Comparison (**CASE 1**)

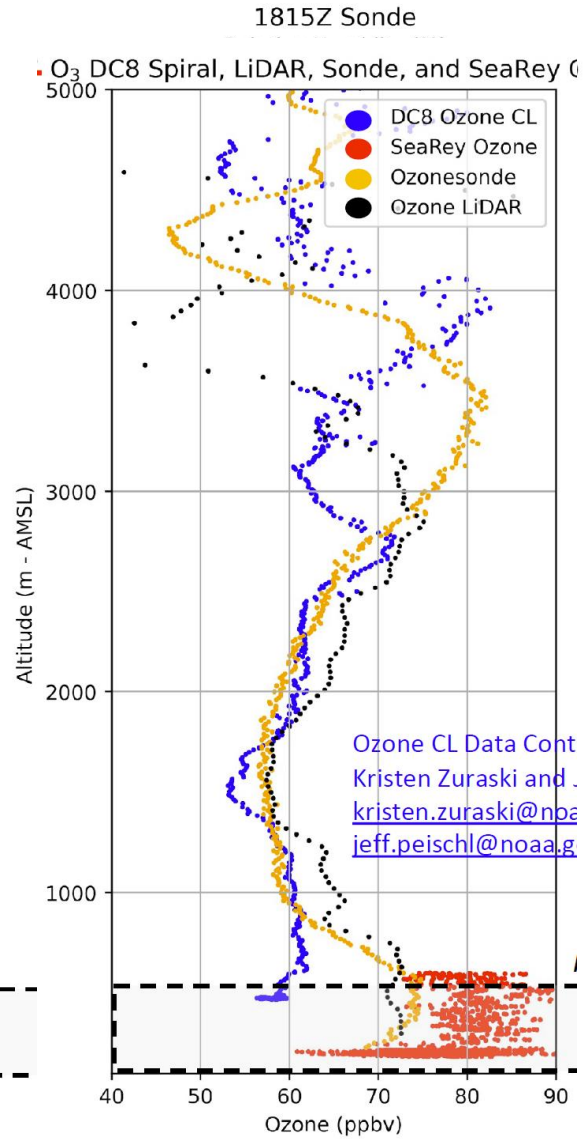
PRELIMINARY DATA



Off the coast of Chiwaukee Prairie

**SeaRey data paired with DC8 data between 18:20:00 UTC to 18:52:00 UTC*





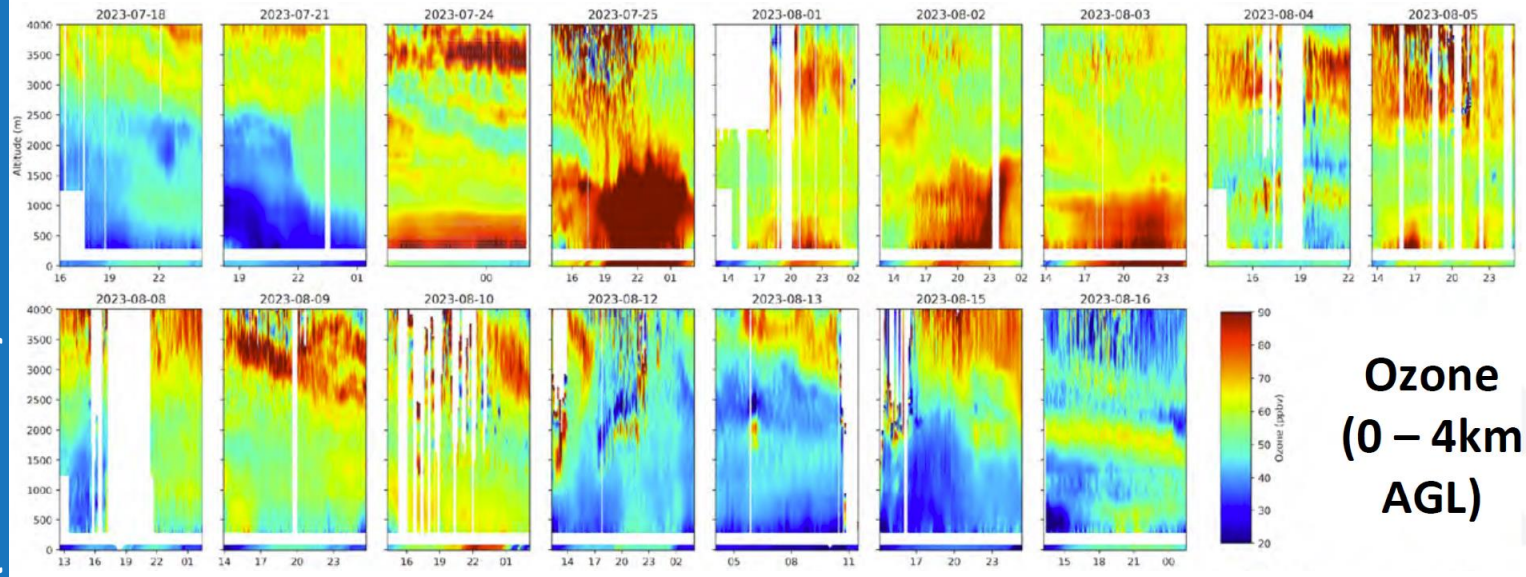
The SeaRey's ability to fly in the lower marine PBL allowed measurements of constituents not possible due to the altitude limits of large aircraft.

Observe the elevated NO_2 levels (**10 ppbv**) just above the lake (**10 – 40 m AGL**) during the August 1 flight. The DC-8 was flying too high to measure these marine PBL gradients effectively. These data will be crucial for the evaluation of TEMPO.

Slide courtesy of Mike Newchurch (UAH)

Mike Newchurch (UAH): LMBreeze campaign, at Chiwaukee

LMBREEZE Measurements: *TOLNet Ozone LiDAR (RO3QET)*

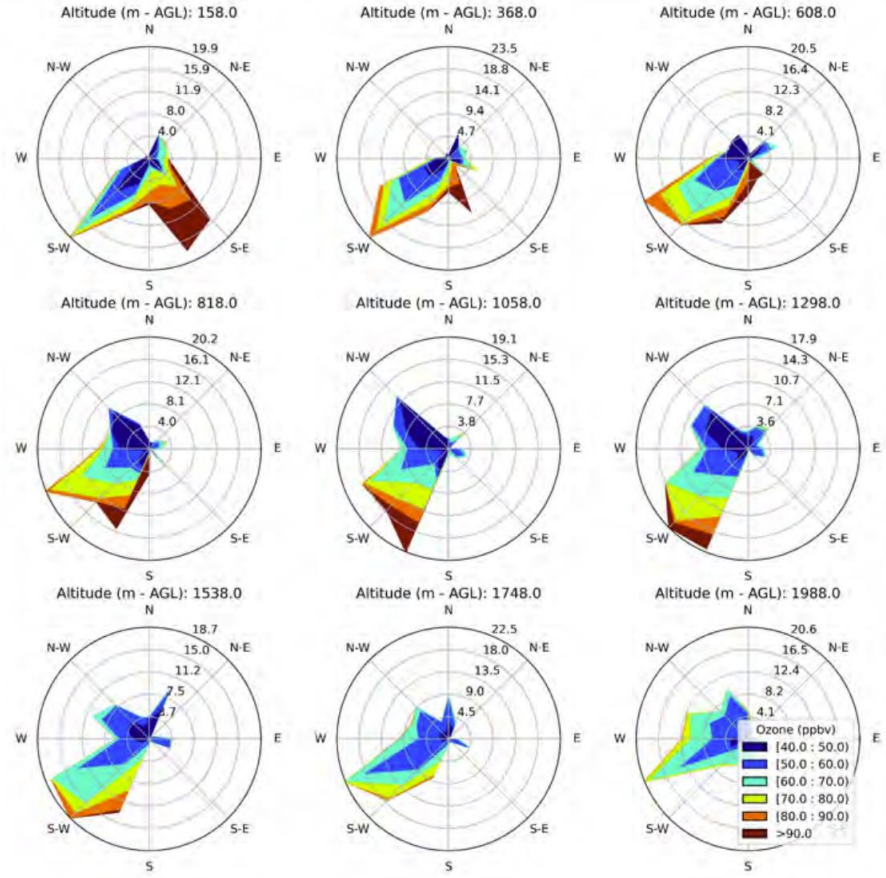


Altitude (0 – 4000 m)

Time

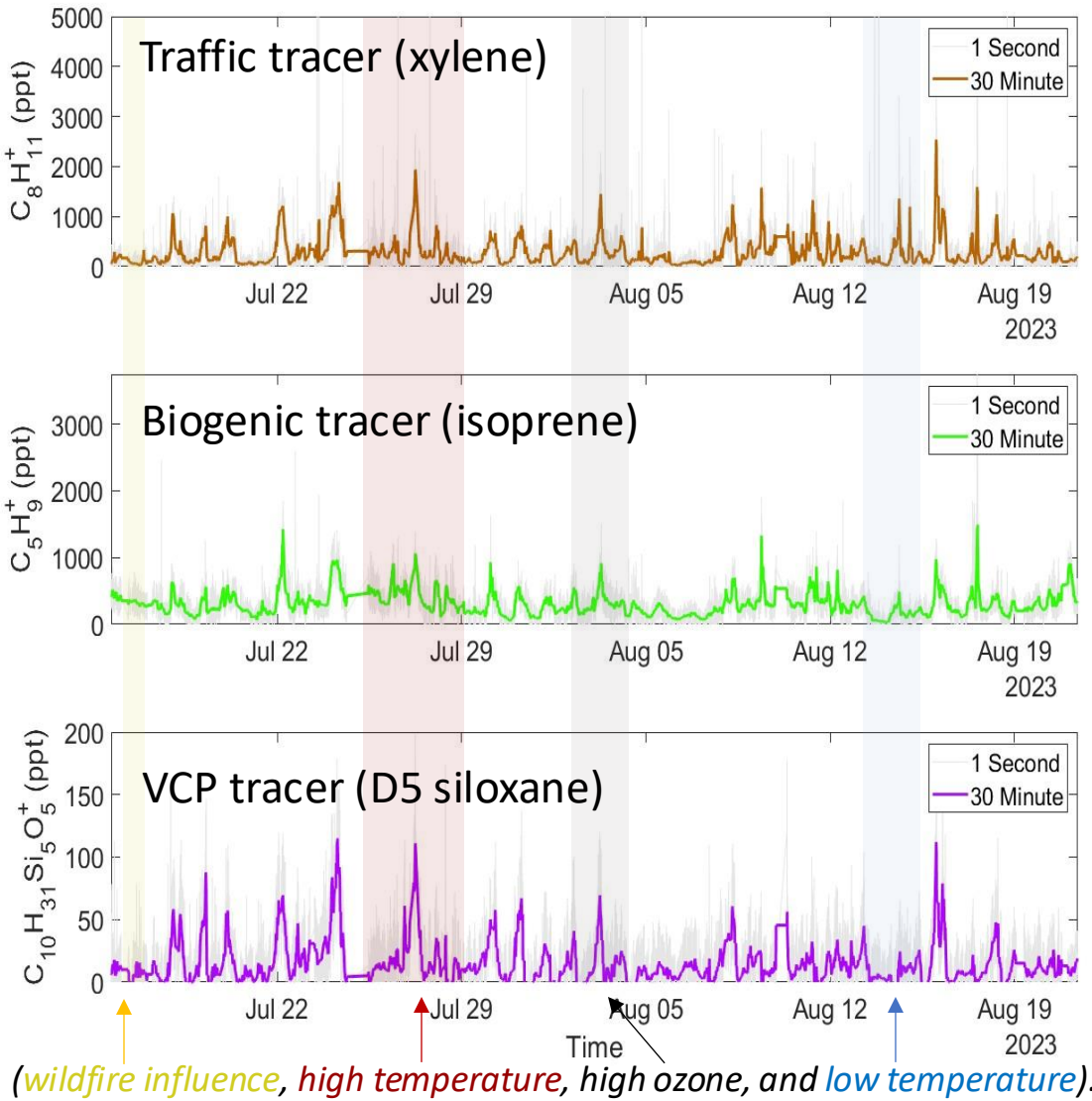
Ozone (0 – 4km AGL)

Ozone versus wind direction and altitude



Left: Ozone (top) and Aerosol (bottom) curtains taken during the campaign duration using the TOLNet LiDAR at Chiwaukee Prairie. **Top:** Wind roses of ozone retrievals parried with UWisc Dopplar Wind LiDAR at 200 m intervals starting at 158 m AGL.

Martina Rogers/Tim Bertram (UW-Madison): VOCs in Chicago



(*wildfire influence*, *high temperature*, *high ozone*, and *low temperature*).

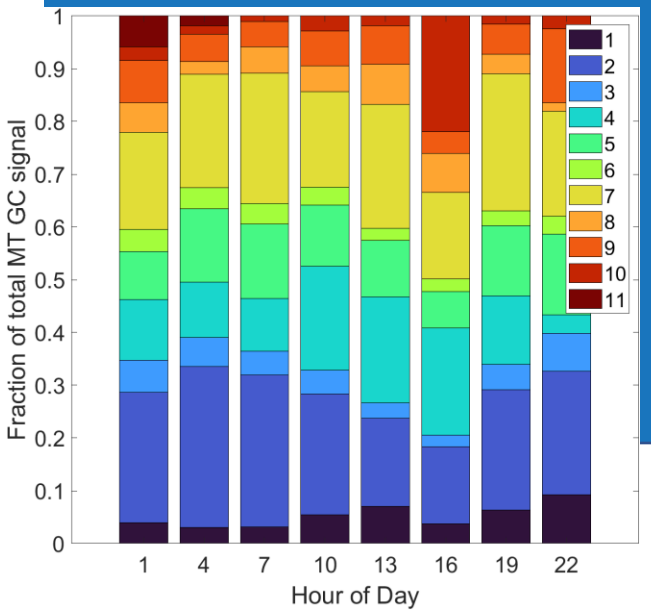
Measurement period: July 15 – August 21, 2023

- Captured days impacted by high ozone and Canadian wildfires

Sampling location: UIC campus

Measured: Over 900 VOC species

Speciate out terpenoids, assess biogenic versus anthropogenic contributions, and calculate OH reactivity and ozone formation potentials.



Average relative contributions to the total GC signal over the course of the day

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Data Availability

- Almost all campaign data is in online data repositories
  - Currently password-protected, but will be public soon (October 1)
  - NOAA repository for AEROMMA data
    - https://csl.noaa.gov/projects/aeromma/data.html
  - NASA repository for all other data
    - https://www-air.larc.nasa.gov/cgi-bin/ArcView/staqs
- TEMPO satellite data is now publicly available

Applications for LADCO

- Studies should lead to improved understanding of:
  - Drivers of summer $PM_{2.5}$
  - Smoke impacts on ozone and $PM_{2.5}$
  - Ozone formation chemistry and meteorology
  - Constraints on emissions

- This should help LADCO and states:
  - Improve models and emissions inventories
  - Design more effective control strategies for $PM_{2.5}$ and ozone

Complete co-authors

Laura Judd: John Sullivan, the NASA Pandora Project, TOLNet, GCAS, HSRL2, HALO and AVIRIS-NG teams
Ann Middlebrook: Alison Piasecki and the AEROMMA team
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Aaron Stainsby: Anna Novelli, Floriann Berg, Michelle Färber, Frank Holland, Hendrik Fuchs, and the AEROMMA team
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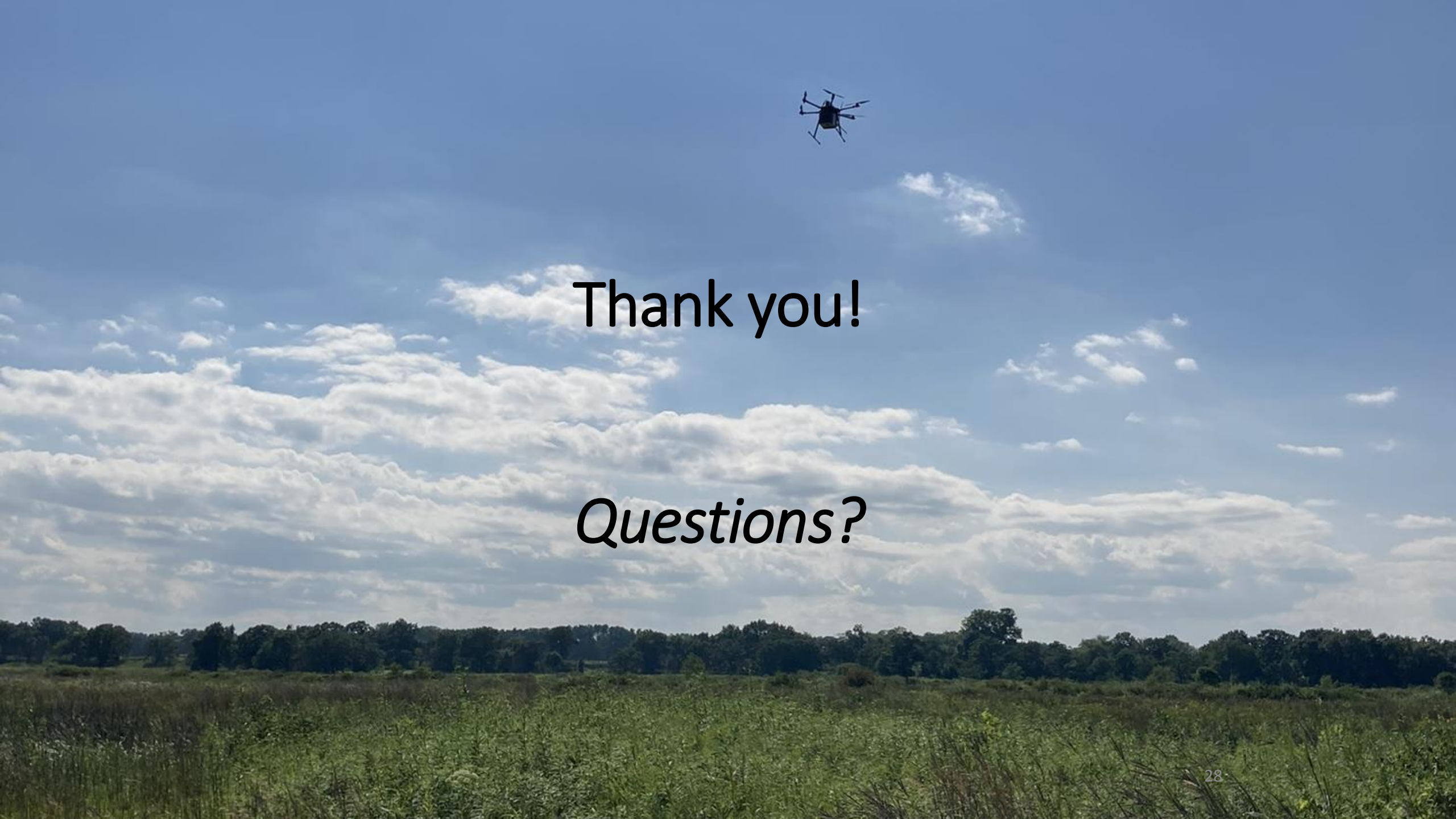

Thank you!

Questions?