


EPRI

LMBREEZE

STUDYING EMISSIONS OVER LAKE MICHIGAN

THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

TEMPO

Mike Newchurch

AiRMAPS Workshop

3-4 September 2024
College Park, MD

Tropospheric Ozone Lidar Network
TOLNet

NOAA 2023
AEROMMA
Atmospheric Emissions and Reactions Observed from Megacities to Marine Areas

Shi Kuang, Todd McKinney, Brad Pierce, Darby Stevenson, Mason Mills, Paula Tucker, Nick Perlaky, Caroline Womack, Steve Brown, Angela Dickens, Cody Converse, Patricia Cleary, Katie Praedel, John Sullivan, Carsten Warneke, Rebecca Schwantes, Laura Judd, Matthew Peckham, Steve Brown, and Caroline Womack.

LMBREEZE

The **Lake Michigan Boundary-Layer Regional Environmental Evaluation of Ozone and Emissions** (LMBREEZE) Campaign expanded on the findings of the **2017 Lake Michigan Ozone Study** (LMOS).

From July 18 to August 16, 2023, the **University of Alabama in Huntsville (UAH)** and the University of Wisconsin (UW) collaborated with the Michigan Department of Natural Resources (DNR) at Chiwaukee Prairie, Wisconsin. Guided by chemical weather forecasting by U Wisconsin/Madison, this campaign investigated the meteorological and photochemical phenomena that impair air quality along the western shore of Lake Michigan.

Summary of Talk

1) Domain and Measurement Summary

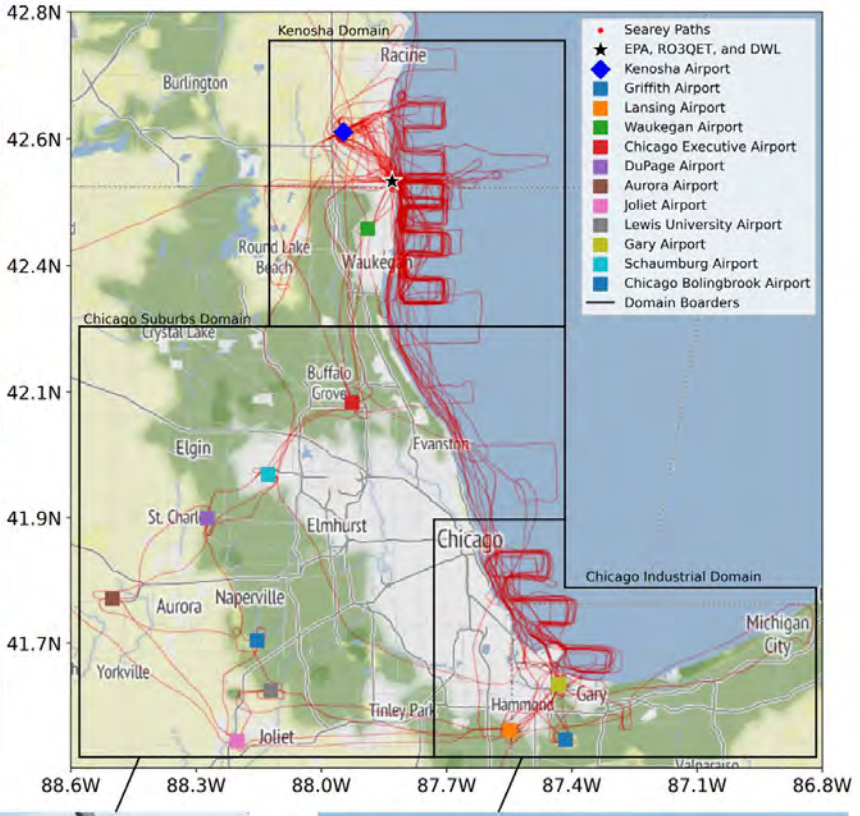
2) *Selected Cases*

Lake Breeze Exceedance Event at Chiwaukkee - July 25th

Spatial Gradients Inside and Outside Lake Breeze Circulations – August 2nd

UAH and NASA DC-8 Measurements (Ozone & NO_2) – August 1st and August 2nd

LMBREEZE Measurements

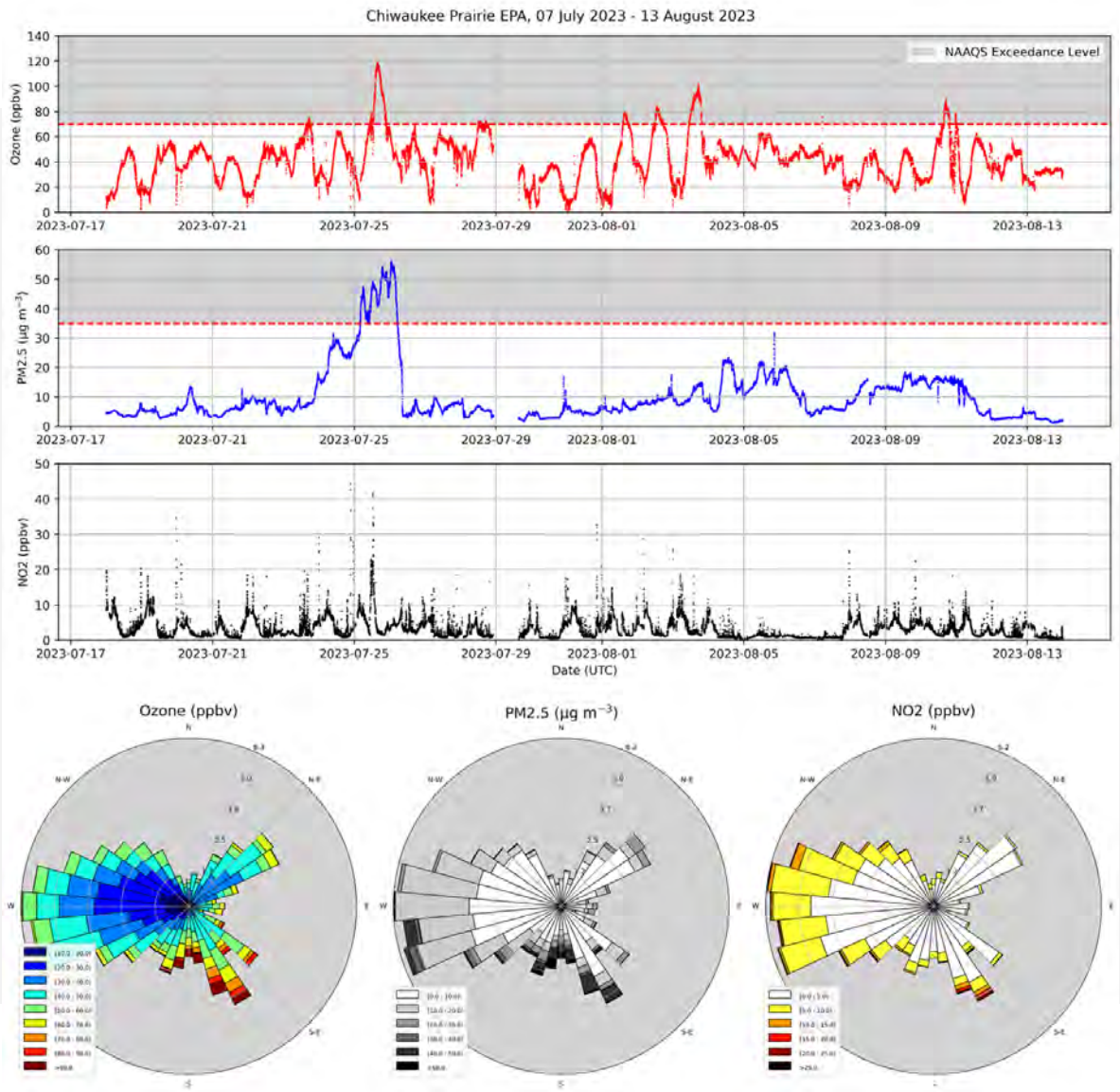


STAQS 2023

UAH R0 Data Achieved at:
air.larc.nasa.gov/missions/staqs

Asset	Total Days	Total Flights	Total Hours
RO_3QET Lidar (ozone DIAL, aerosol backscatter, 2 minute/100 m resolution, 0-10,000m altitude)	21	N/A	113
SeaRey (CSL mACES NO2, 2B 205, 2B POM, UAH custom PM/T/RH: 1m to 4,000m AGL available)	19	41	82
Drone Profiles (2B POM, UAH custom PM/T/RH): 0 - 120m AGL)	16	180	60
Windsondes (0-10,000m)	29	65	N/A
Ozonesondes (0-30,000m)	9	12	N/A
RO3QET Surface Measurements	30	N/A	710
UWisc Doppler Wind Lidar (0-2000m)	40+	N/A	960+

LMBREEZE Measurements: ***Surface***

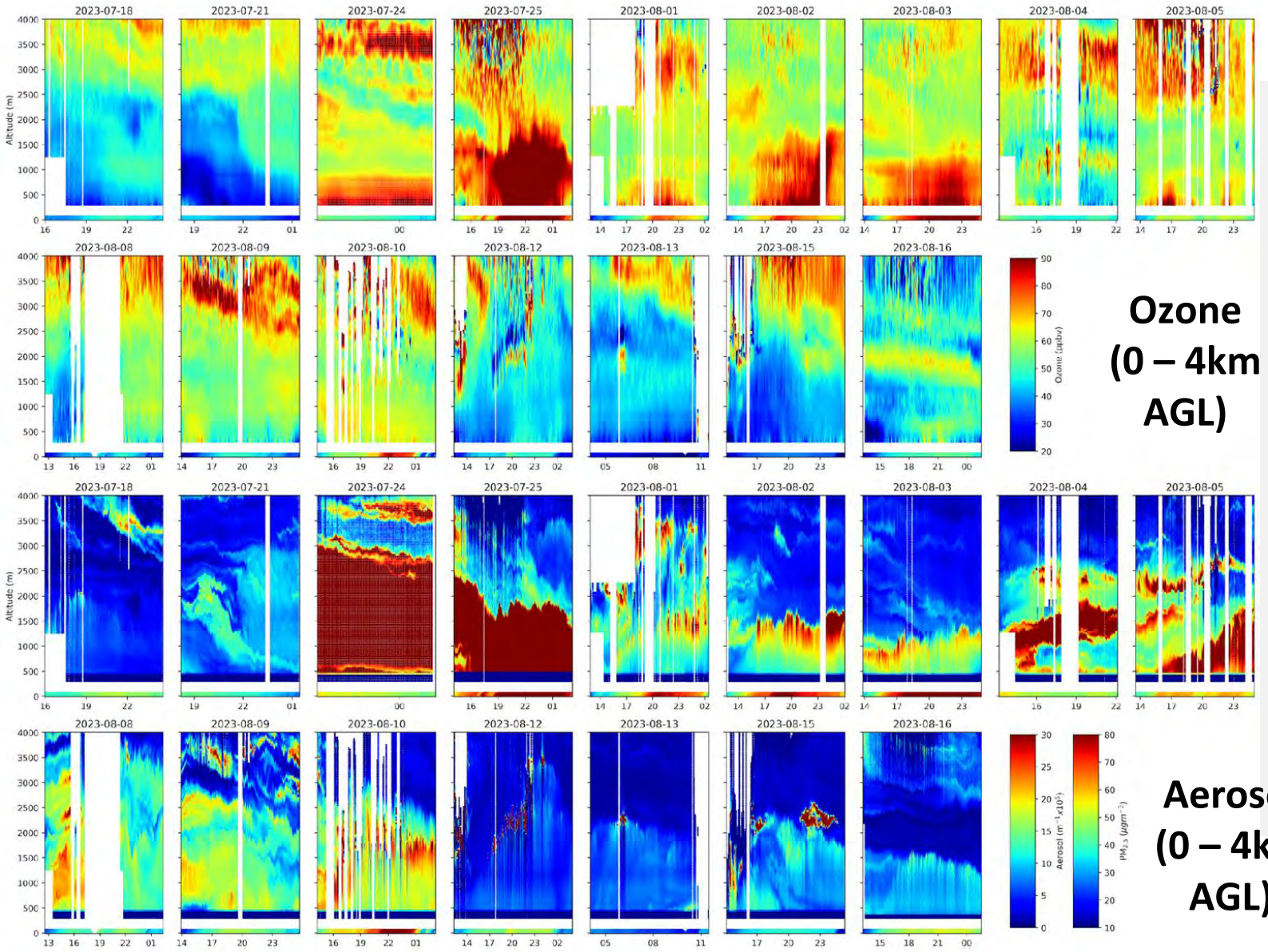


While **ozone exceedances** have dropped for both states over the last 30 years, **Kenosha County** still has, on average, more exceedances every year compared to Wisconsin and Illinois state averages.

- This exceedance frequency has important policy implications, as previous studies have shown that these exceedances are not the fault of the local area; rather, it is the *transport of emissions* from the south that causes them.

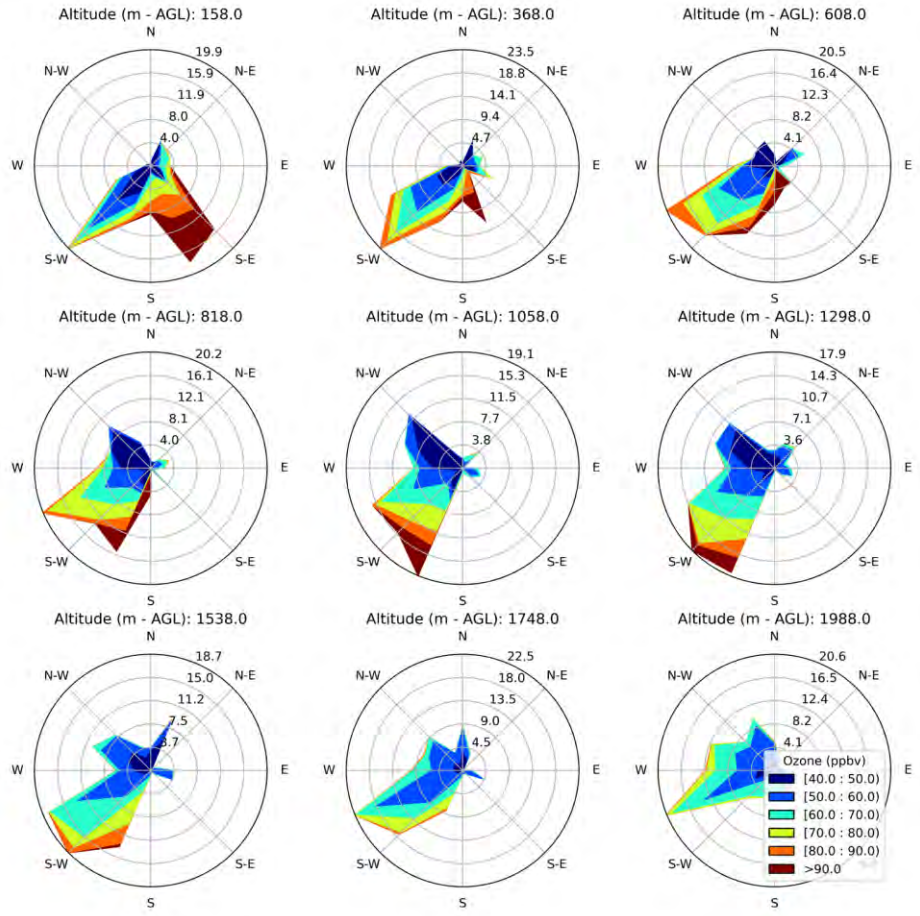
Left: *EPA surface measurements from Chiwaukkee during the UAH campaign duration. Throughout the 30-day deployment period, ozone NAAQS limits were exceeded on eight days. The majority of high concentrations of ozone, $PM_{2.5}$, and NO_2 originated from the south-southeast, (i.e., Chicago).*

LMBREEZE Measurements: *TOLNet Ozone LiDAR (RO3QET)*



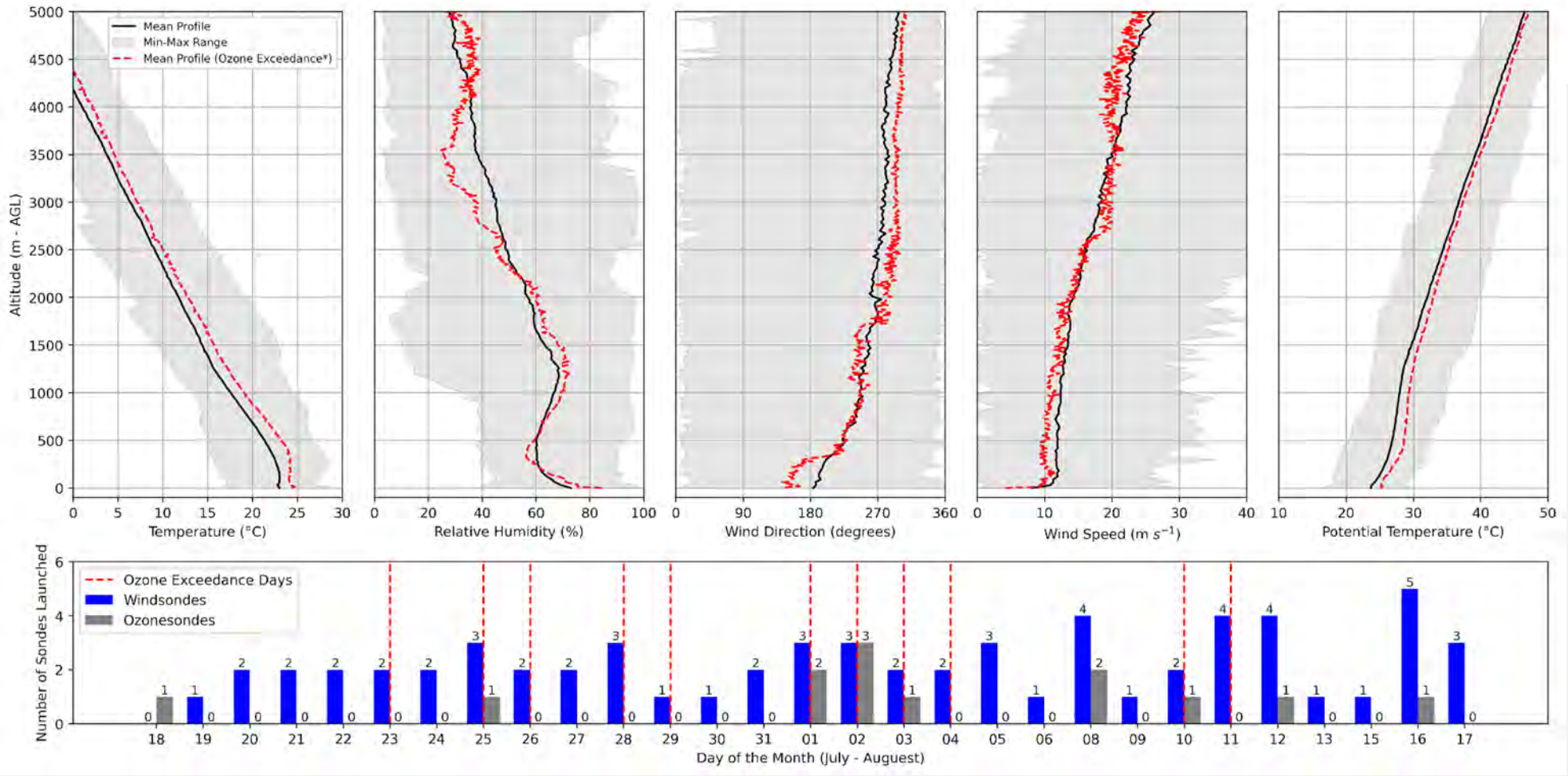
Ozone (0 – 4km AGL)

Aerosol (0 – 4km AGL)



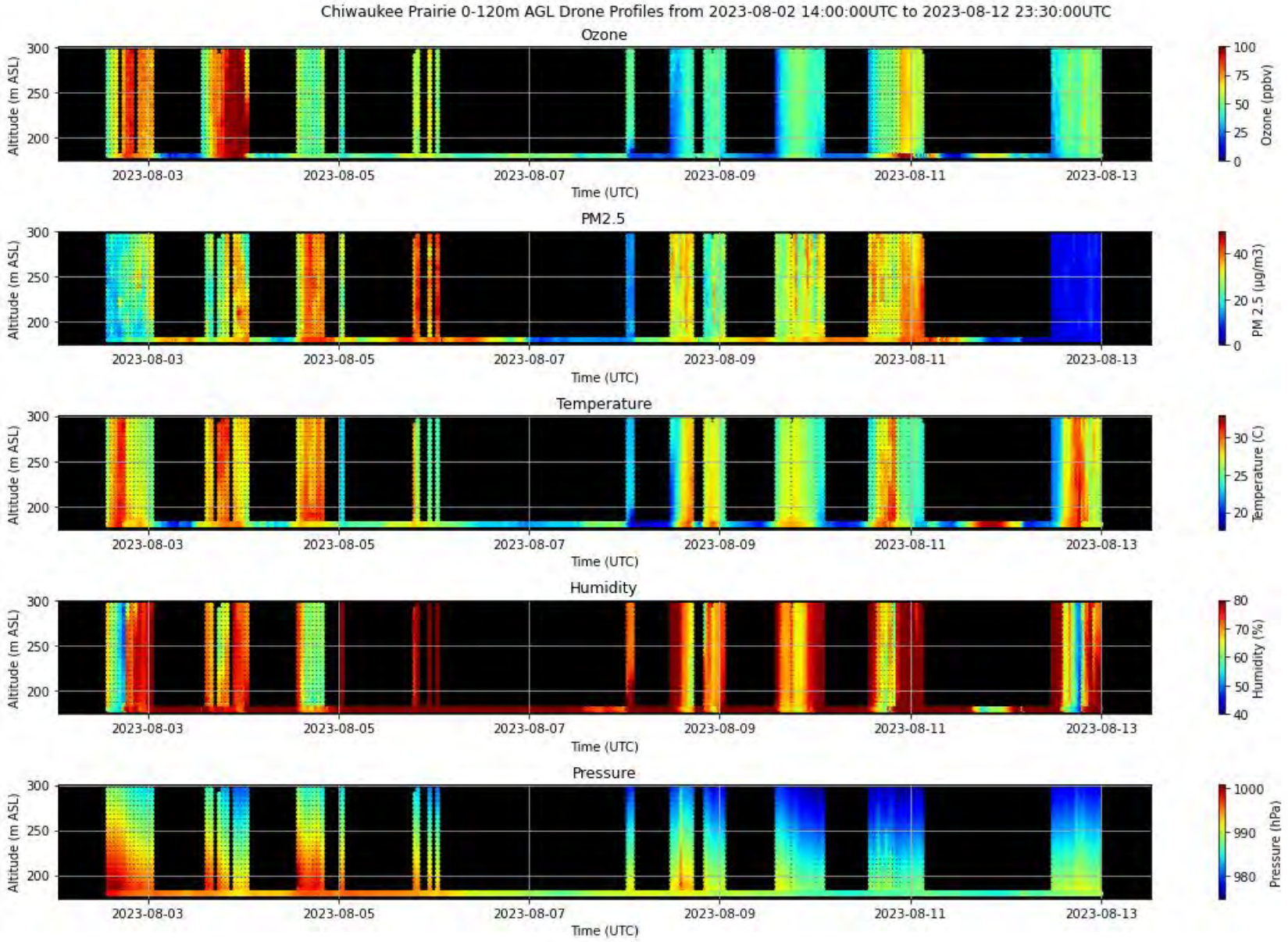
Left: Ozone (top) and Aerosol (bottom) curtains taken during the campaign duration using the TOLNet LiDAR at Chiwaukee Prairie. **Top:** Wind roses of ozone retrievals parried with UWisc Dopplar Wind LiDAR at 200 m intervals starting at 158 m AGL.

LMBREEZE Measurements: ***Sondes***



Mean, min, and max atmospheric profiles measured from the 63 windsondes and 10 ozonesondes launched from Chiwaukee Prairie during the campaign duration. *A separate **mean red line** is plotted for sondes launched when surface ozone was above 70 ppbv. Bottom plot displays the number of windsondes and ozonesondes launched per day as well as the when ozone >70 ppbv.

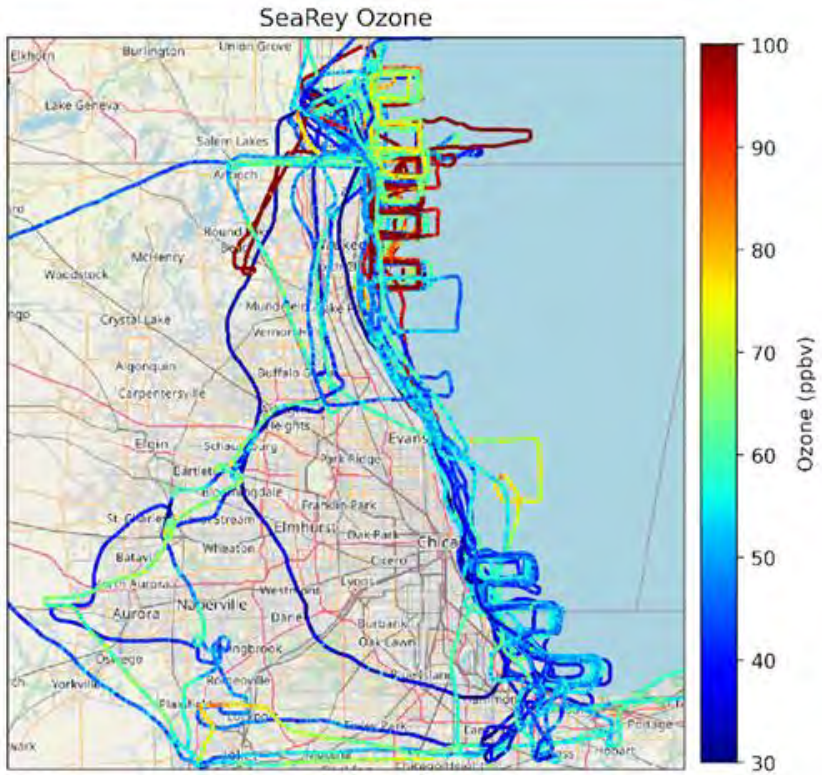
LMBREEZE Measurements: ***Drones***

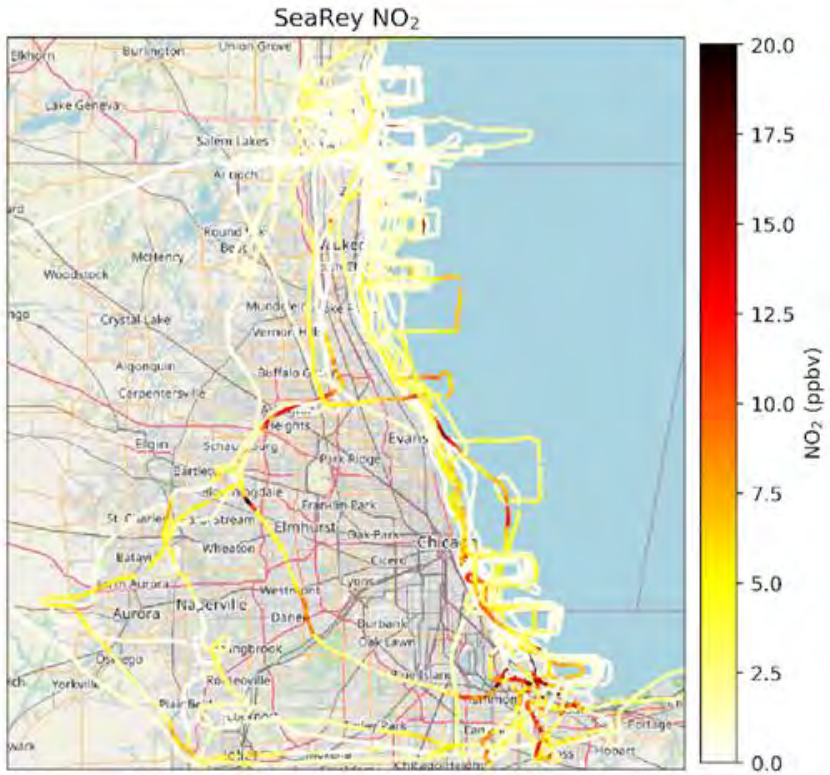


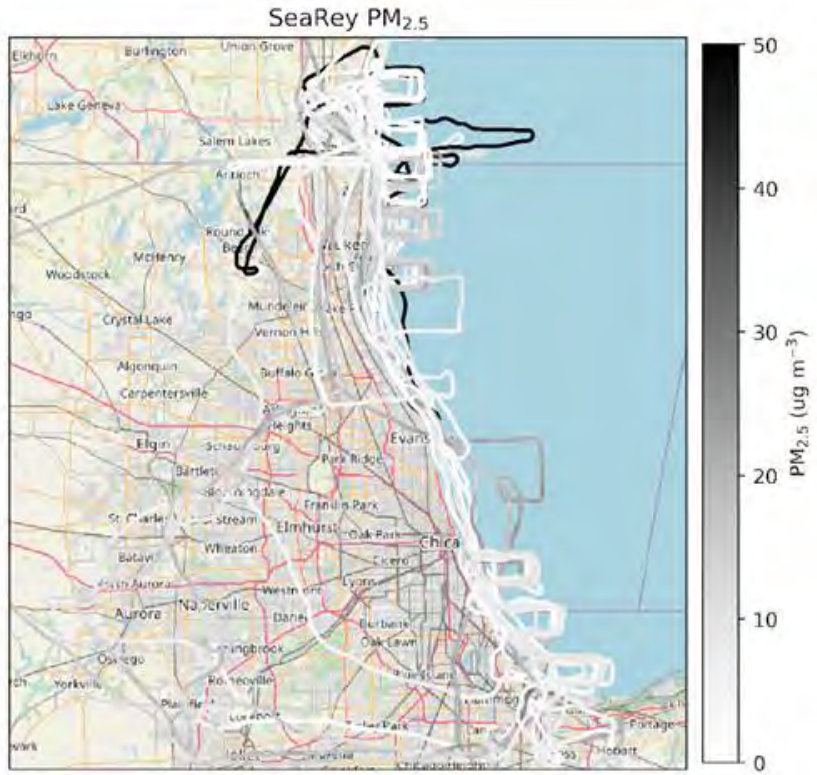
The UAH UAV was operated at Chiwaukee Prairie from the UAH RO3QET site, and its primary role was to make regular vertical soundings of the lower boundary layer.

- Over the duration of the campaign, the drone made a total of **180 flights over 16 flight days.** Each flight provided a profile of the atmosphere from the surface to 120 meters AGL.
- The drone provided supplemental data to the UAH RO3QET LiDAR as well as the surface ozone measurements, bridging the ozone LiDAR data void that occurs between the surface and about **100 meters AGL.**

LMBREEZE Measurements: ***SeaRey***



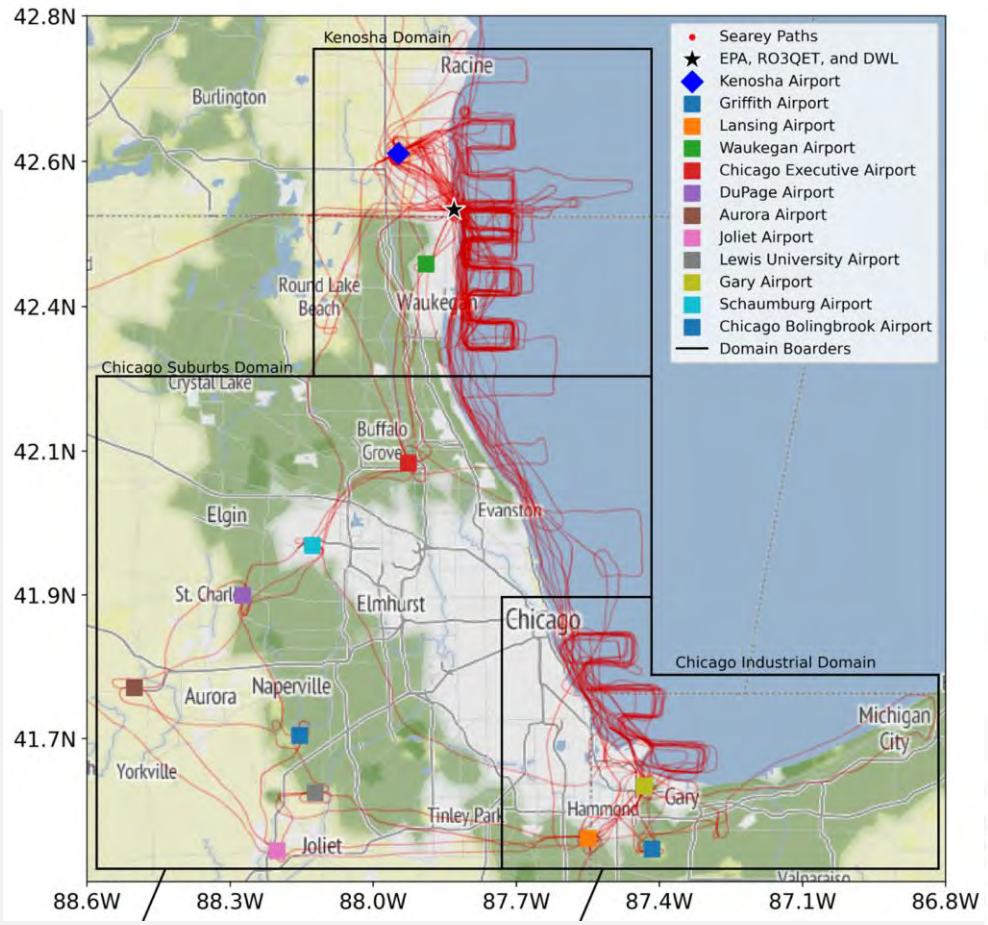


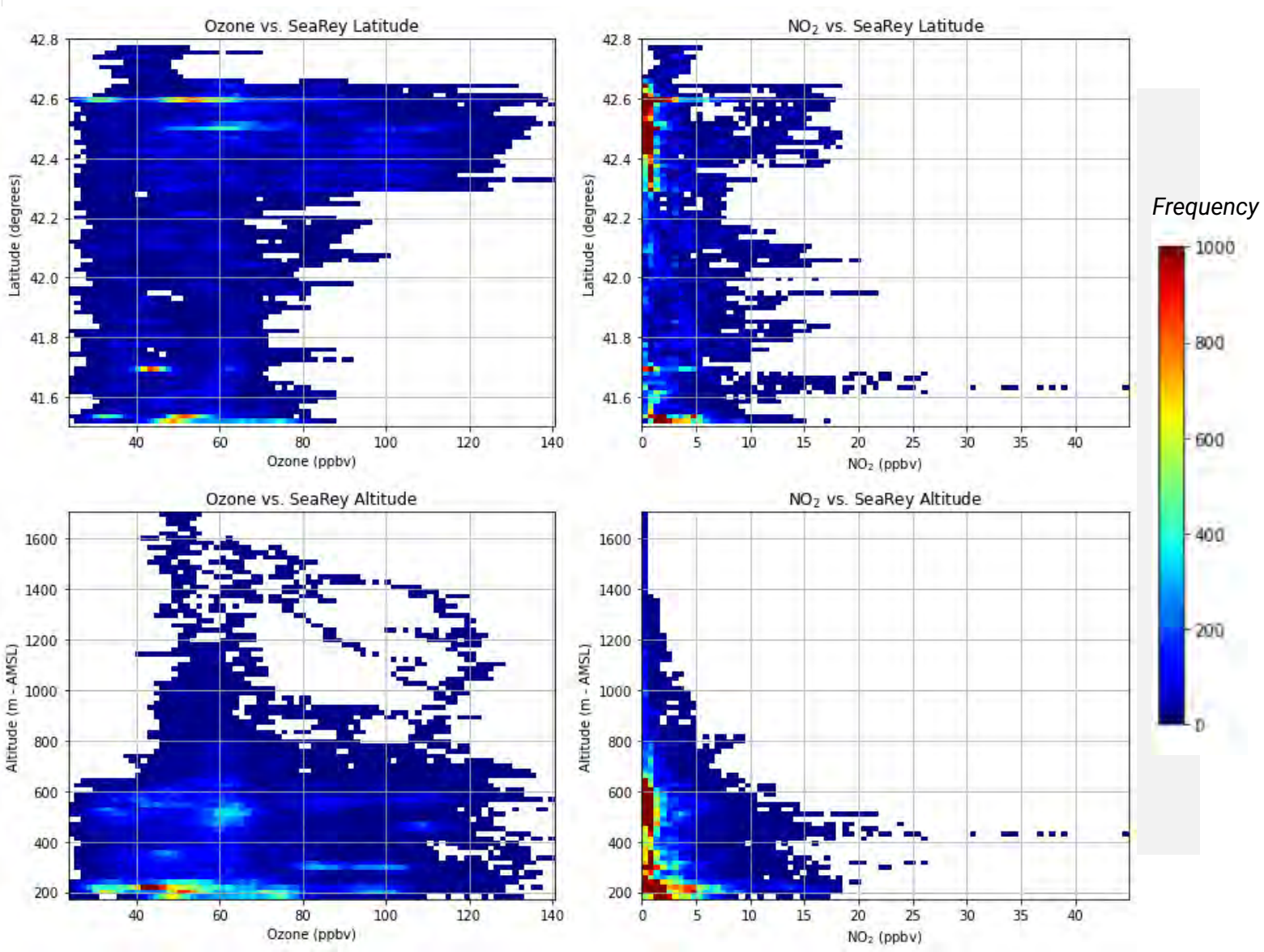


The **Progressive Aerodyne SeaRey** is an amphibious aircraft that makes lower-boundary-layer insitu measurements of ozone, $PM_{2.5}$, NO_2, temperature, pressure, and humidity. Real-time, two-way data communication between the a/c and the RO3QET lidar and other instruments occurs through cell towers and voice comms over aircraft radio. This aircraft is especially useful for maritime studies, as it can *fly very close to and land* on the water.

Top figure: Flight paths of the SeaRey during the campaign colored by ozone, NO2, and PM2.5.

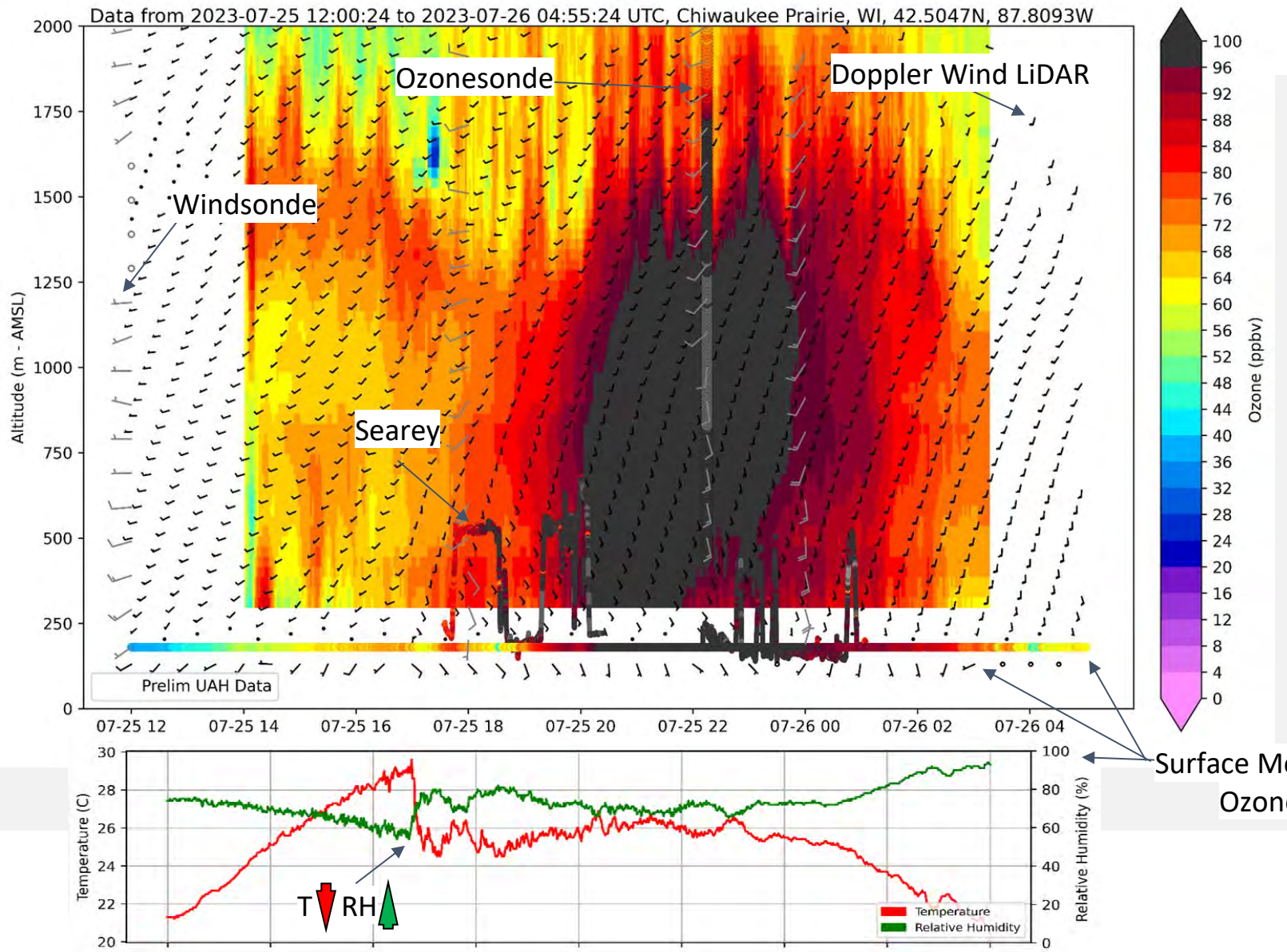
SeaRey Ozone and NO_2 Distributions





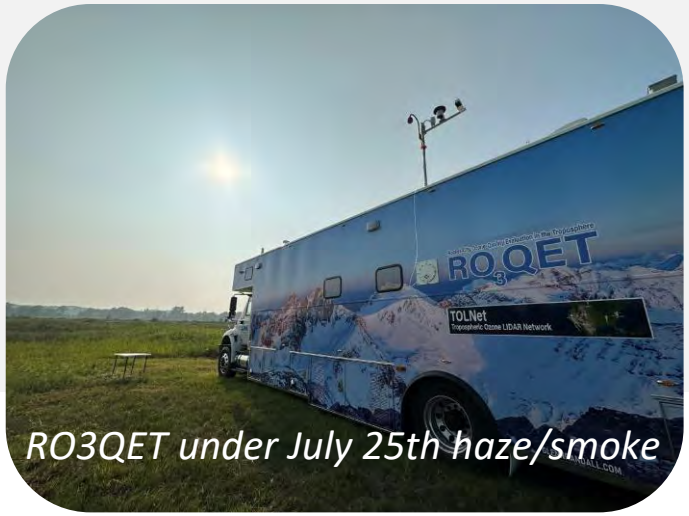
Distributions sorted by latitude (top) and altitude (bottom) of ozone (left) and NO_2 (right) measured by the SeaRey during the campaign.

Example Lake Breeze Exceedance Event - July 25, 2023



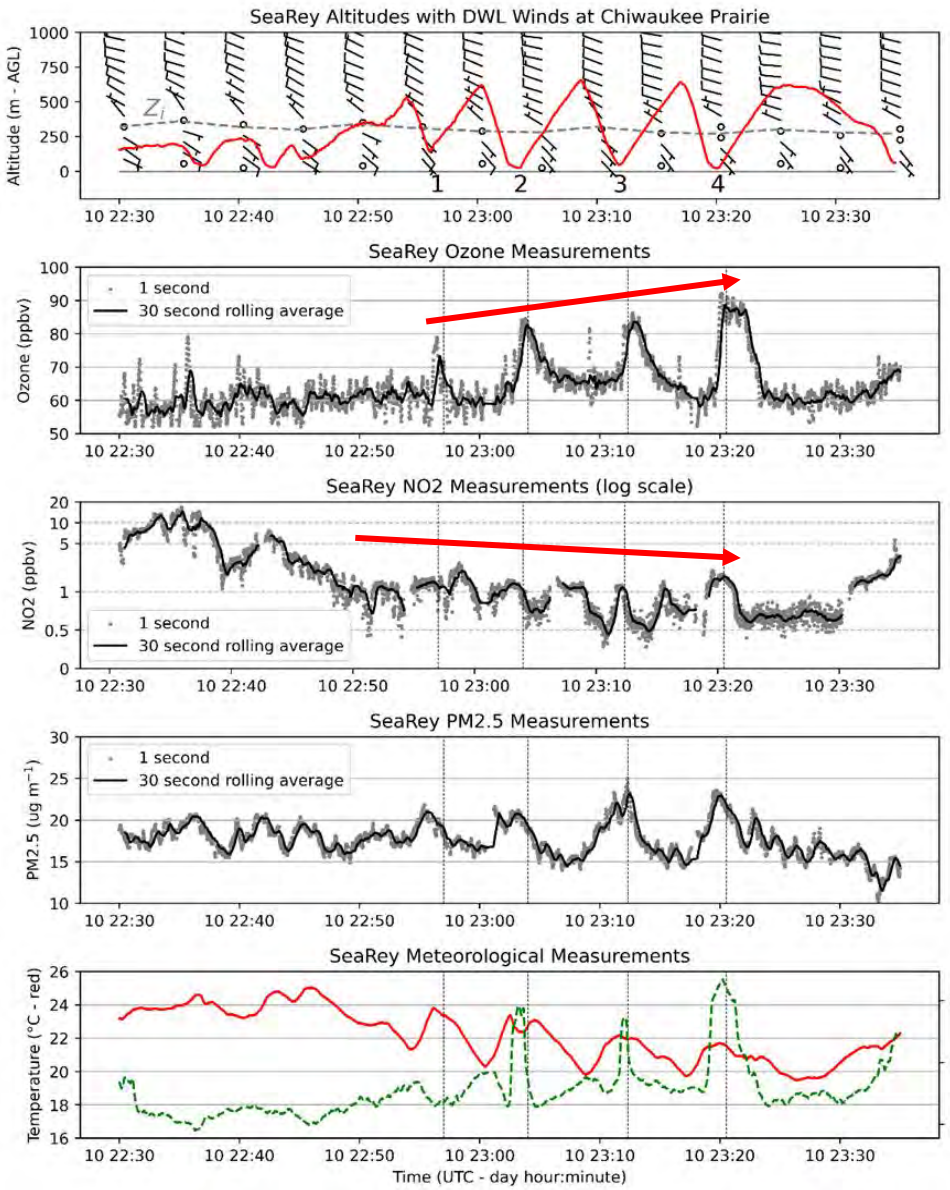
We captured an ozone-exceedance event on July 25, 2023, where ozone mixing ratios at the surface peaked at **117 ppbv** and **125-150 ppbv** near 1 km.

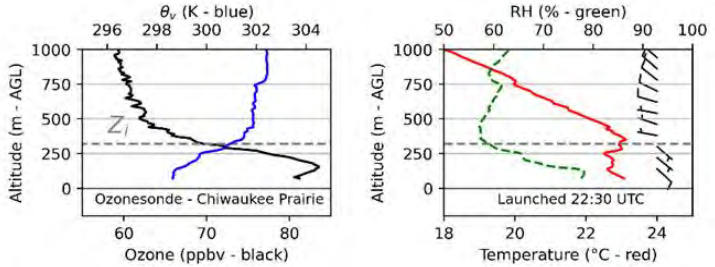
- The interaction between **smoke** transported from Canadian wildfires, *emissions* carried from **Chicago**, and marine boundary-layer dynamics is complex.
- UAH assets provide insight at high *temporal and spatial resolution.*

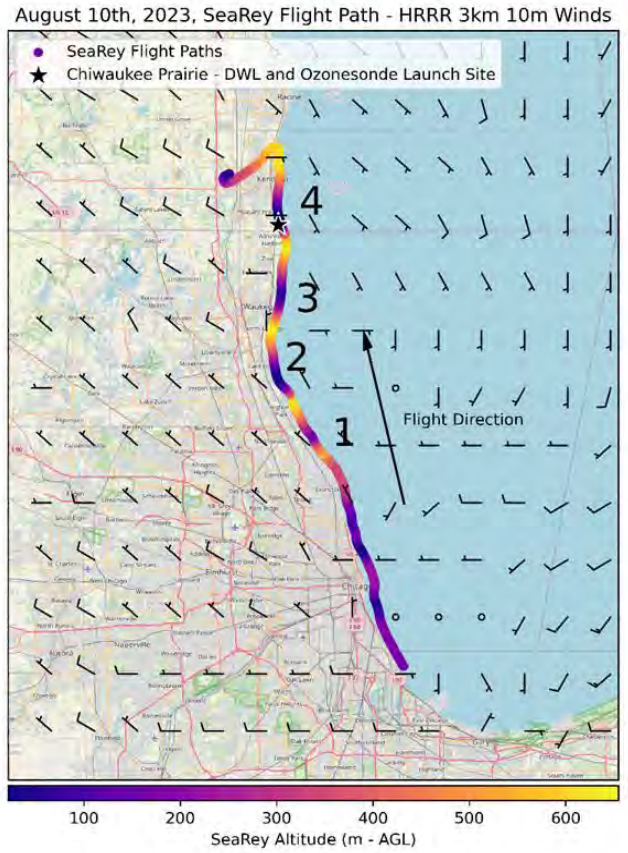


RO3QET under July 25th haze/smoke

Spatial Gradients Inside and Outside Lake Breeze Circulations – August 2nd





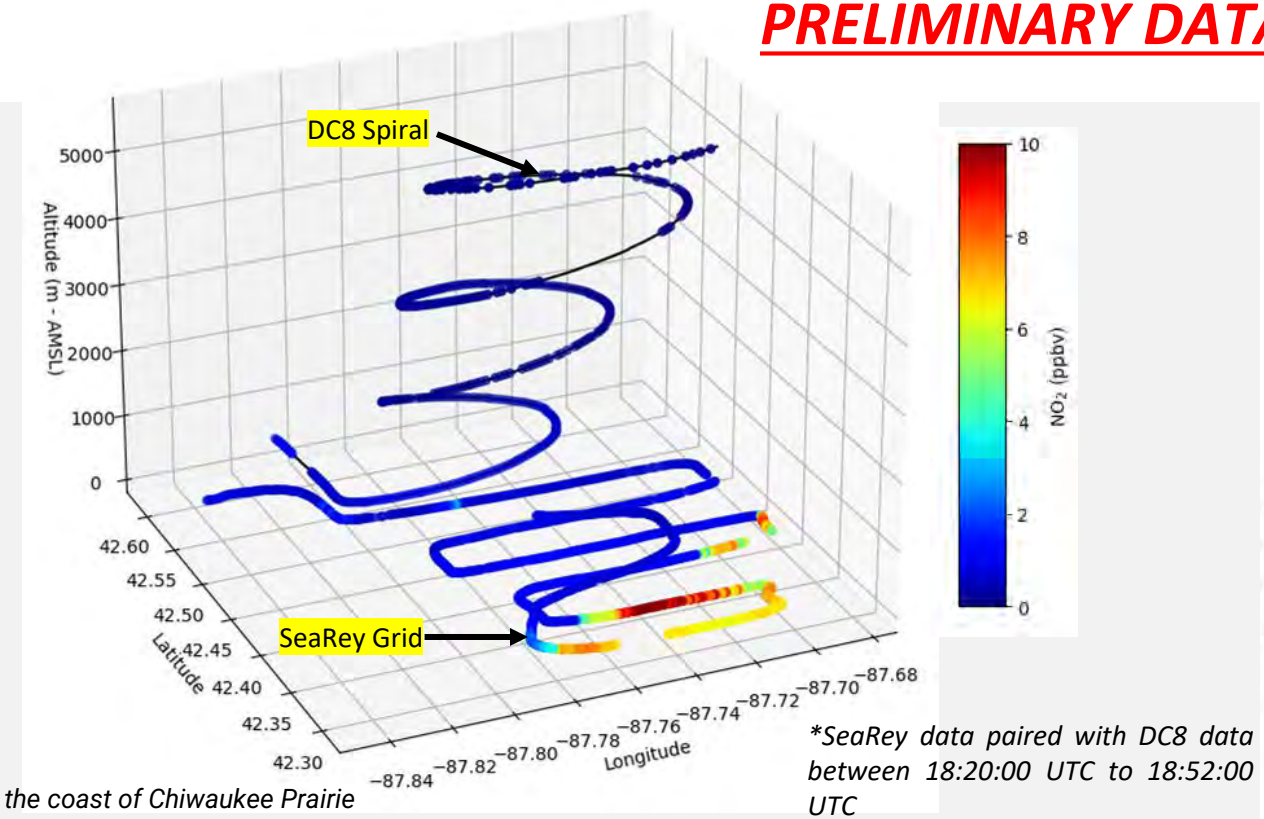


On the SeaRey's flight from **Chicago to Kenosha** on August 10, 2023, it was instructed in real time to **porpoise** above and below the Lake Breeze circulation.

The aircraft's altitude, DWL winds, ozone, NO_2, PM2.5, and meteorological measurements are plotted against time. Additionally, a map displaying the flight track colored by altitude, accompanied by HRRR 3km wind barbs at 10m AGL at 23Z, is presented. In the top right corner, data from an ozonesonde launched from Chiwaukee is shown, with Z_i indicating the boundary layer height. Notations 1,2,3,4 represent the four respective porpoises minima inside the PBL.

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

PRELIMINARY DATA

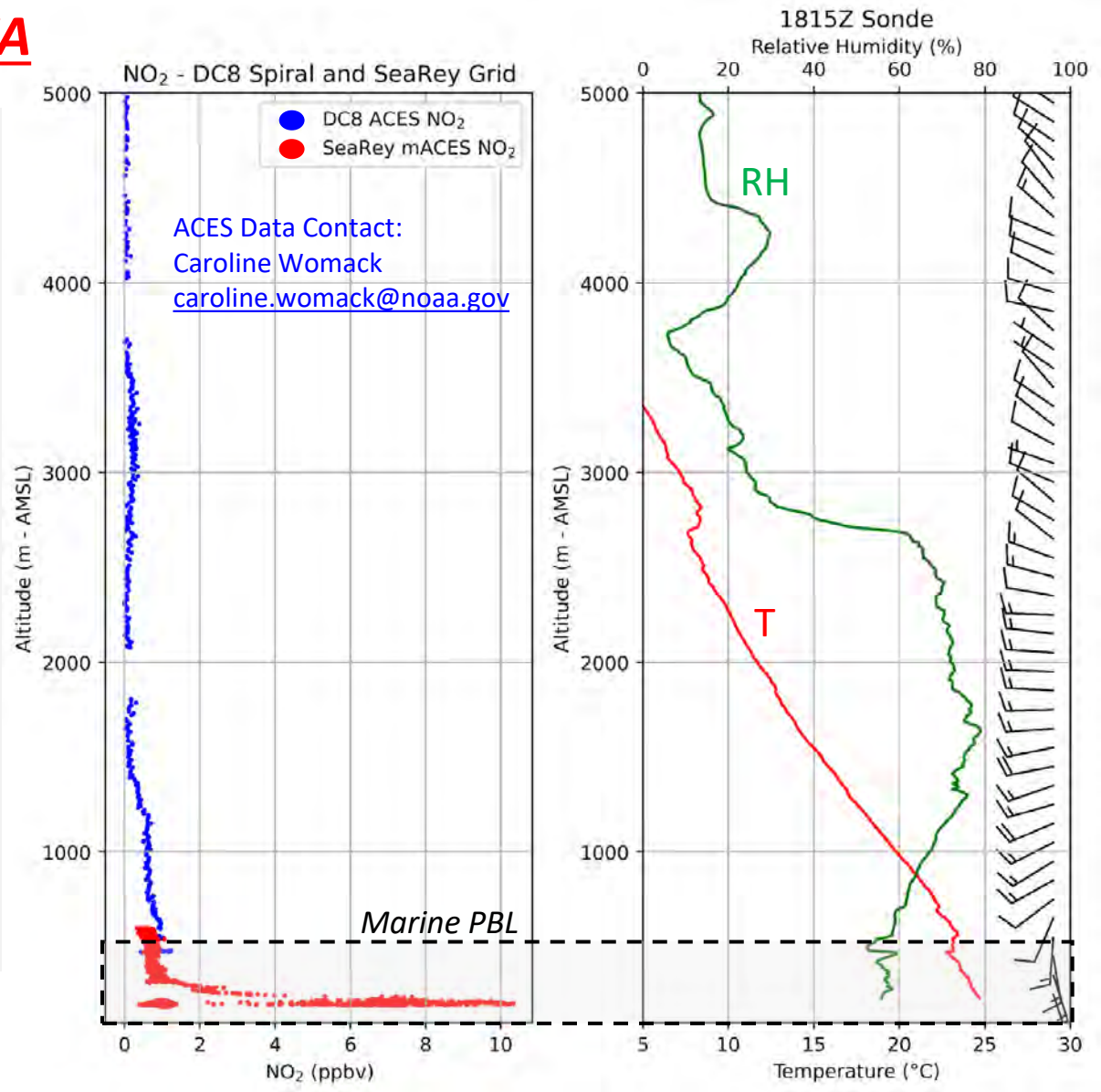


Off the coast of Chiwaukee Prairie

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

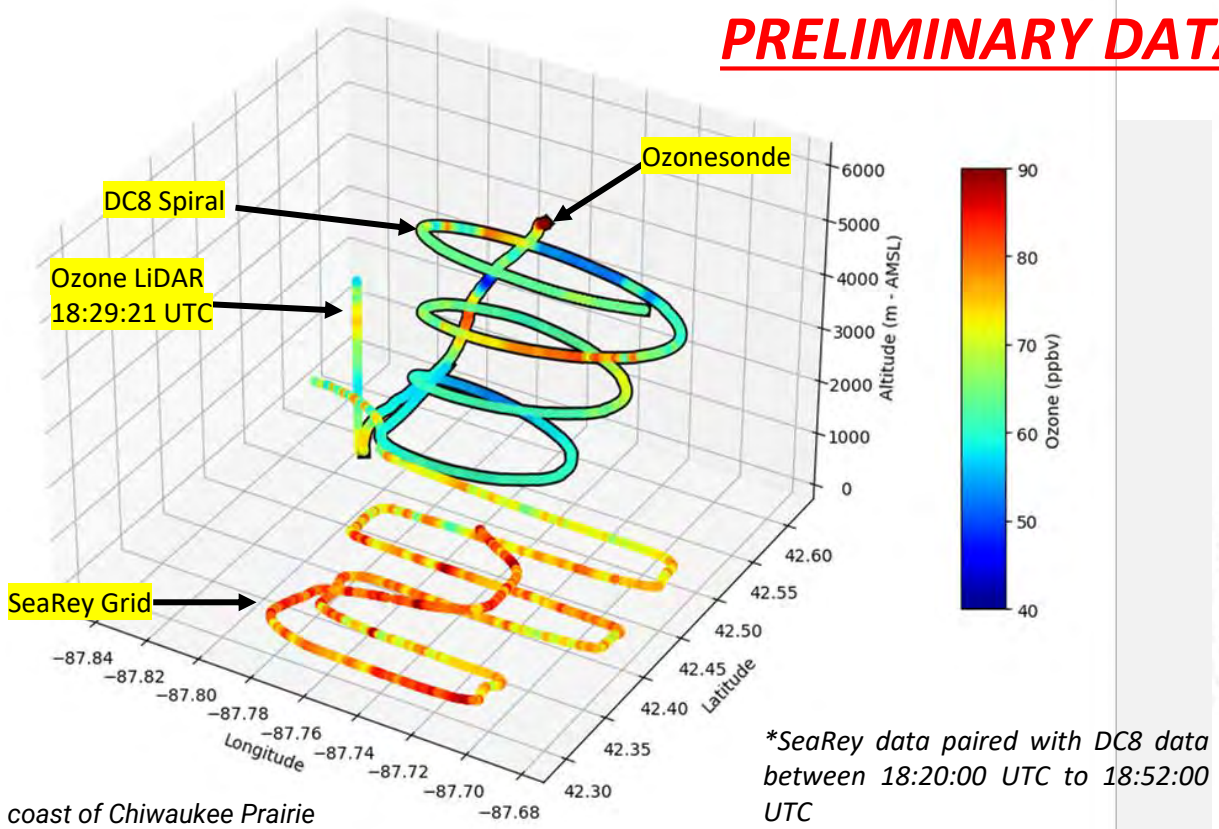
The SeaRey's ability to fly in the lower marine PBL allowed measurements of constituents not possible due to the altitude limits of large aircraft.

- 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.



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

PRELIMINARY DATA

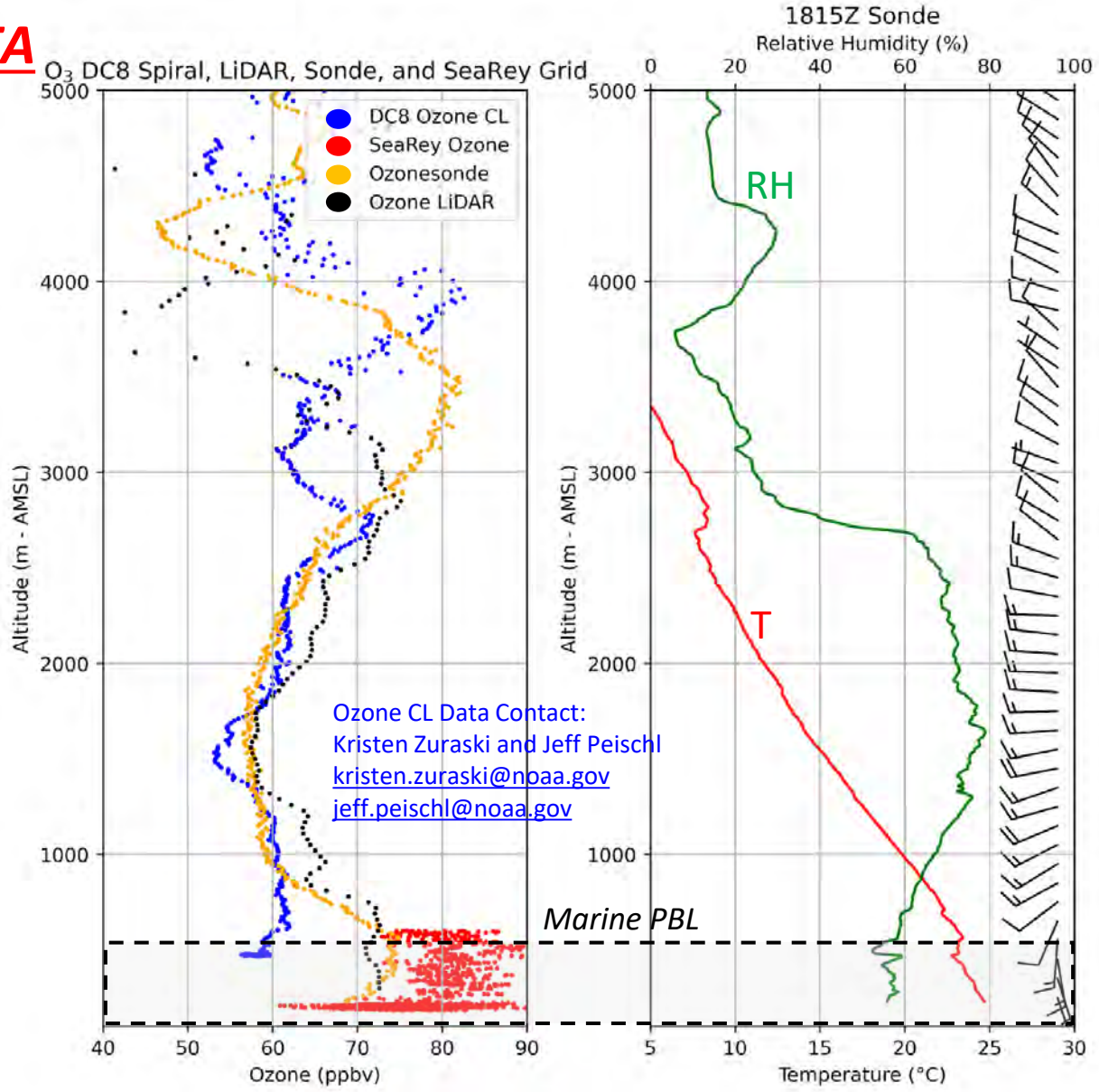


Off the coast of Chiwaukee Prairie

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

Comparison of all ozone assets on August 1 during the DC-8 18:20:00 UTC spiral.

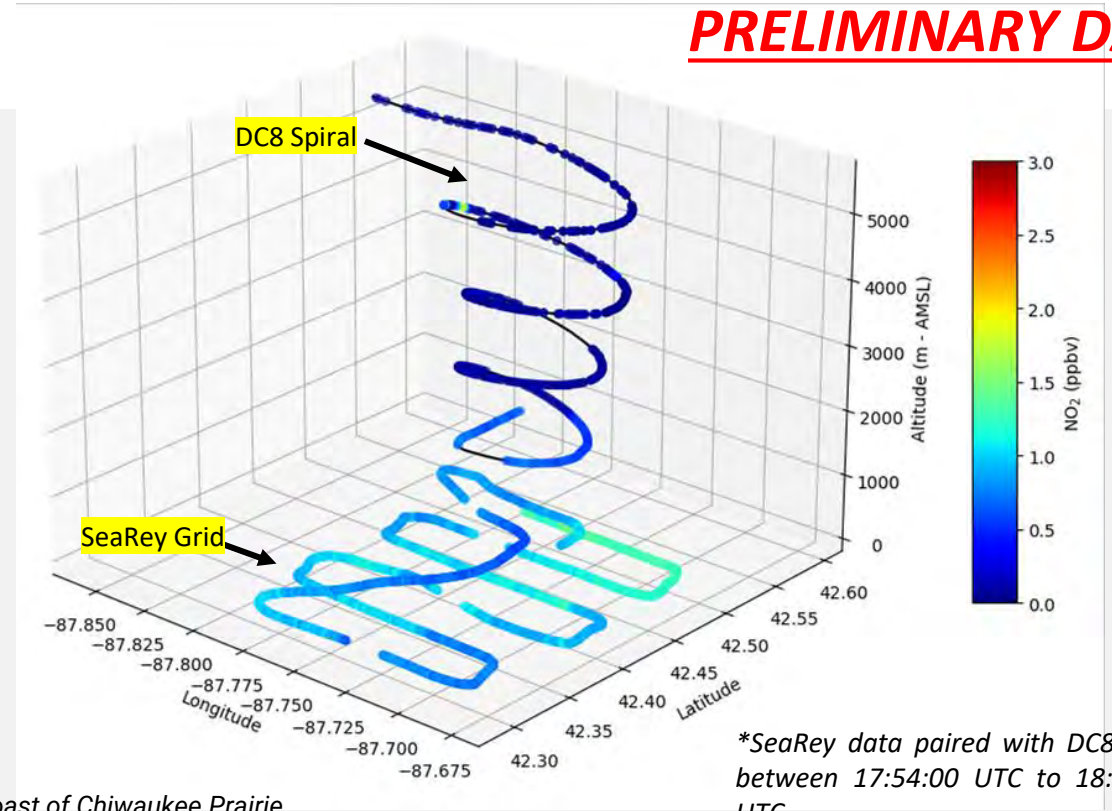
- The distribution of ozone within the lower marine PBL proximate to the lake surface exhibits considerable complexity and heterogeneity compared to other observational platforms. This observation is corroborated by measurements of NO_2 concentrations in the same region.



Ozone CL Data Contact:
Kristen Zuraski and Jeff Peischl
kristen.zuraski@noaa.gov
jeff.peischl@noaa.gov

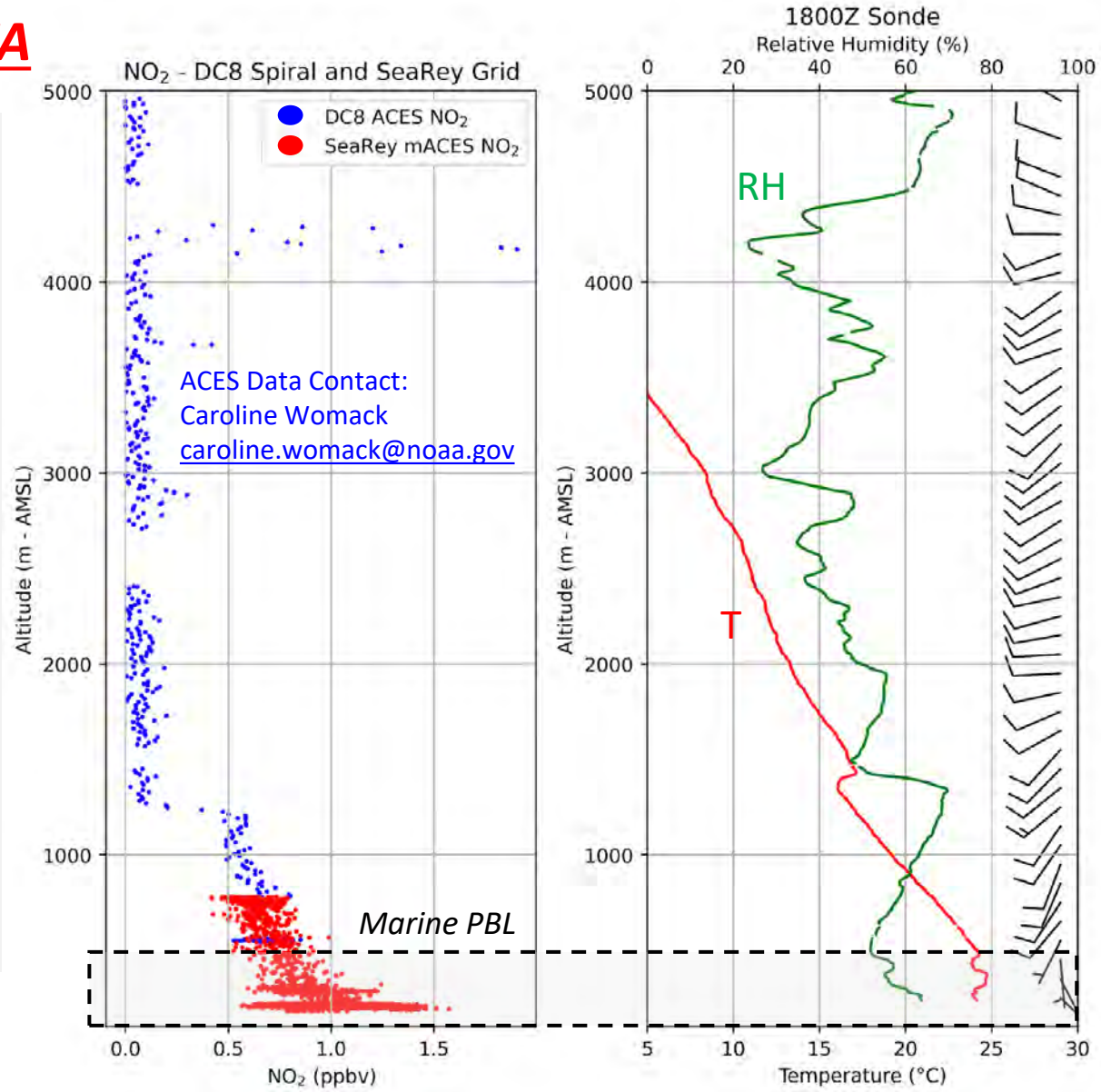
August 2, 2023 – SeaRey vs. DC-8 NO_2 Comparison (**CASE 2**)

PRELIMINARY DATA



Off the coast of Chiwaukee Prairie

**SeaRey data paired with DC8 data between 17:54:00 UTC to 18:45:00 UTC*

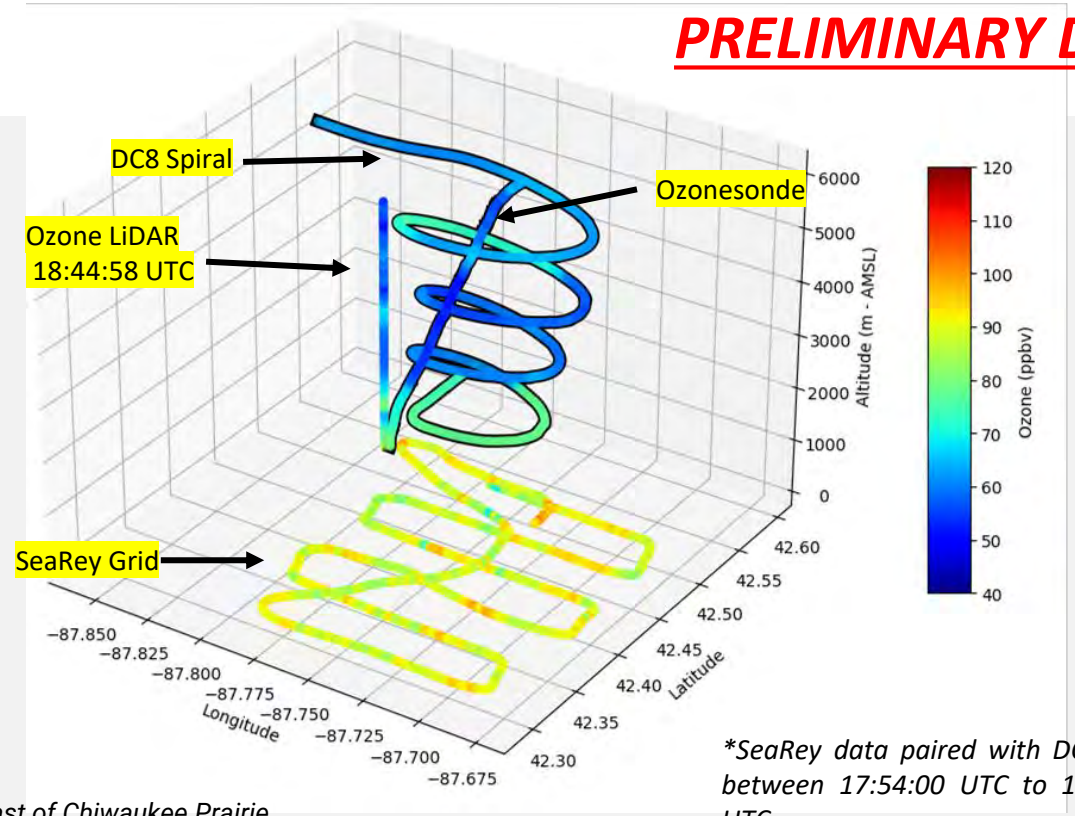


August 2nd had lower NO_2 in the marine PBL, but the trends from the previous day remain.

- DC-8 ACES and SeaRey mACES align well (+- 0.1 ppbv) on altitude overlaps.

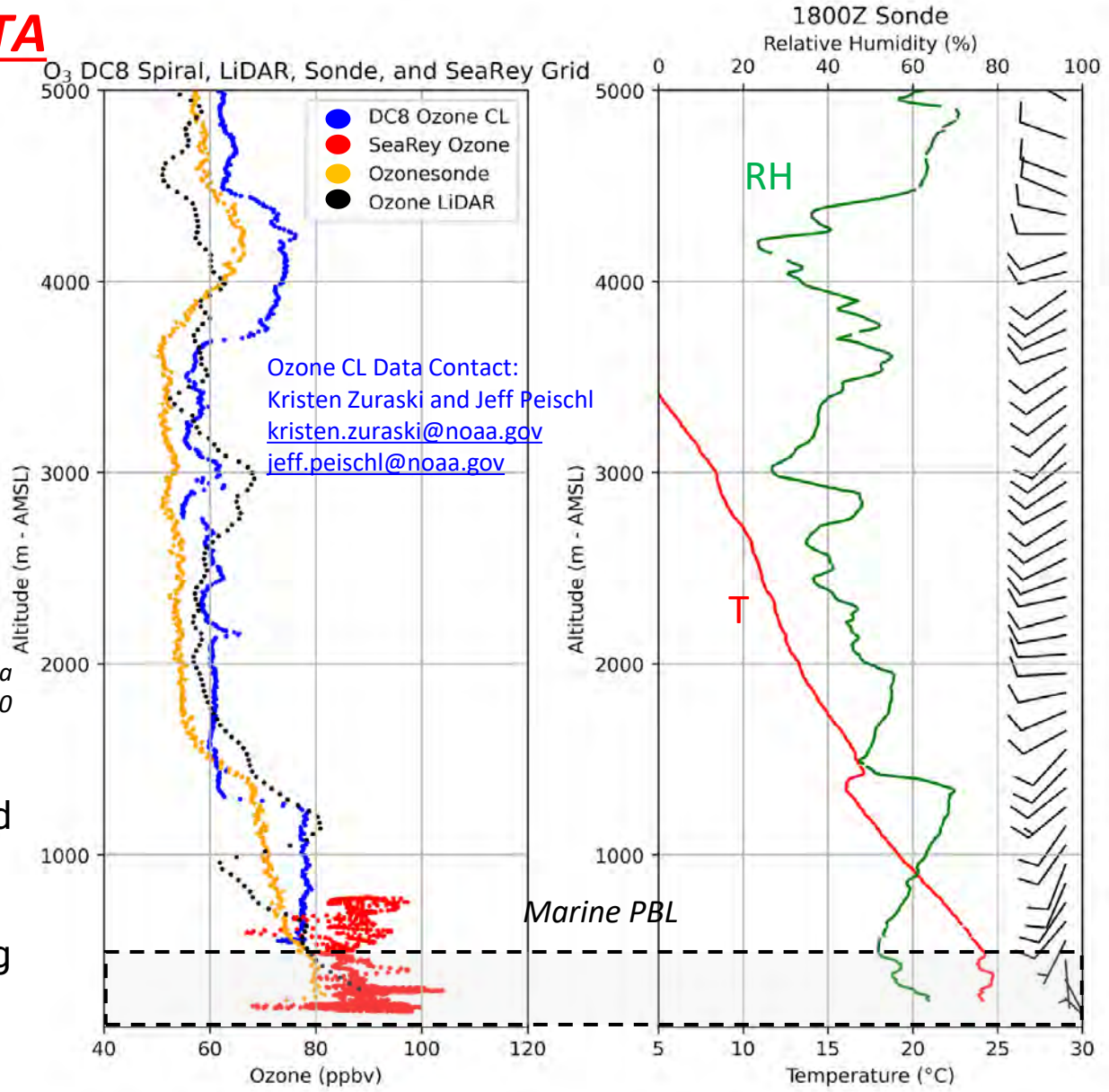
August 2, 2023 – SeaRey vs. DC-8 **Ozone** Comparison (**CASE 2**)

PRELIMINARY DATA



Off the coast of Chiwaukee Prairie

**SeaRey data paired with DC8 data between 17:54:00 UTC to 18:45:00 UTC*



Ozone CL Data Contact:
Kristen Zuraski and Jeff Peischl
kristen.zuraski@noaa.gov
jeff.peischl@noaa.gov

Higher ozone in the marine PBL but more homogenous compared to August 1st

- Comparisons between well-mixed days and those exhibiting steep gradients will be critical for the evaluation of TEMPO.

Conclusions

- ***From July 18 to August 16, 2023, the LMBREEZE team successfully collected critical measurements of the 4-D distributions of ozone, NO_2, PM, and meteorology.***

- The lowermost marine boundary layer **(10 – 40 m AGL)** frequently exhibits the most significant gradients across various constituents.

- These measurements of both the vertical **and horizontal** distribution of gases and aerosols will contribute the validation of TEMPO precision and accuracy, especially in the PBL.

- These measurements along with theoretical analyses contribute to our understanding of the transport and photochemistry of primary pollutants from their respective sources.