2023 Mobile and Offshore Air Quality Monitoring

FINAL REPORT

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List of Abbreviations

AAE	Absorption Ångström Exponents
AGL	Height above ground level
amp	Ampere
AQI	Air Quality Index
AQRP	Air Quality Research Program
BEIS	Biogenic Emission Inventory System
BLC	Blue light converter
BU	Baylor University
C	Celsius
CAMS	Continuous Ambient Monitoring Stations
CAMx	Comprehensive Air Quality Model with Extensions
CB6r5	Carbon Bond version 6 revision 5
CFD	Computational fluid dynamics
cm^2	square centimeters
cm^3	cubic centimeters
CO	Carbon Monoxide
CPA	Chemical process analysis
CST	Central Standard Time
CTAQO)	Coastal Texas Air Quality Observations
DOAS	Differential Optical Absorption Spectroscopy
DOE	Department of Energy
eBC	equivalent Black Carbon
ECC	electrochemical concentration cell
FAA	Federal Aviation Administration
FM	Farm-to-Market Road
GPS	Global Positioning System
GCO	Ground control operator
HCHO	Formaldehyde
HEPA	High efficiency particulate air
HGB	Houston-Galveston-Brazoria
HSC	Houston Ship Channel
IOP	Intensive Operations Period
jNO_2	Photolysis rate of NO_2
km	kilometer
LAANC	Low Altitude Authorization and Notification Capability
LIDAR	Light Detection and Ranging
LOD	Lower limit of Detection
m	meter
met	Meteorological
MAQL1	Mobile Air Quality Lab 1
MAQL2	Mobile Air Quality Lab 2
MDA8	Maximum Daily 8-hour Average
NAAQS	National Ambient Air Quality Standard
NASA	National Aeronautics and Space Administration
NO	Nitric Oxide
NO_X	Oxides of Nitrogen
NO_2	Nitrogen Dioxide
NO_Y	Total Reactive Nitrogen

O_3	Ozone
Ox	Oxidants (O_3 + NO_2)
ppbv	parts per billion by volume
P	Pressure
PBLH	Planetary boundary layer height
PGA	Proposal for Grant Activities
POPS	Portable Optical Particle Spectrometer
PTR-MS	Proton Transfer Reaction – Mass Spectrometry
PTR-ToF-MS	Proton Transfer Reaction – Time of Flight – Mass Spectrometry
RAD	Rapid Alkene Detector
RH	Relative Humidity
RPIC	Remote Pilot in Command
s	seconds
SAE	Scattering Ångström Exponents
SEU	St. Edward's University
SIP	State Implementation Plan
SO_2	Sulfur Dioxide
T	Temperature
TAMU	Texas A&M University
TEMPO	Tropospheric Emissions: Monitoring Pollution satellite
TRACER	TRacking Aerosol Convection Interactions ExpeRiment
TRACER-AQ1	TRACER-Air Quality 1
TRACER-AQ2	TRACER-Air Quality 2
TCEQ	Texas Commission on Environmental Quality
UH	University of Houston
VOC	Volatile Organic Compounds

EXECUTIVE SUMMARY

The 2023 Mobile and Offshore Air Quality Monitoring project (PGA#582-23-43296-028) successfully deployed two new mobile laboratories on land and water and launched 24 ozonesondes from land and water. Drone flights were conducted at the University of Houston (UH) campus as well as the UH Coastal Center. The September 2023 deployment also saw four separate ozone episodes with six days with special observations of the Tropospheric Emissions: Monitoring of Pollution (TEMPO) instrument which NASA had recently launched. These special observations aligned with three of the ozone episodes and collected data scans across the Gulf Coast, including Houston, every ten minutes for two hours each day. These special observations were a part of the Coastal Texas Air Quality Observation experiment which was conducted in coordination with NASA's commissioning and testing phase and was proposed by this PI team as well as the TCEQ project managers.

To support the 2023 Mobile and Offshore Air Quality Monitoring program a modified Freightliner box truck based out of the La Porte airport similar to the air quality measurements operations in 2021 and 2022 which were also supported by TCEQ using a smaller mobile air quality lab. In 2023 an additional collaboration was established with Texas A&M researchers which resulted in the use of a time-of-flight proton-transfer reaction mass spectrometer to resolve numerous volatile organic compounds in high time resolution. The offshore component saw the first deployment of a modified 30' research boat which was able to traverse Galveston Bay with a larger instrument payload and at much greater speeds than was possible with the pontoon boat which had been deployed in 2021 and 2022 for TCEQ and AQRP. The additional capabilities of this boat were also highlighted by trips into the Gulf of Mexico, as much as 20 miles offshore, allowing targeted sampling of ships waiting in the anchoring areas and sampling emissions from an offshore platform. Ozone sondes were launched from the boat both in Galveston Bay and in the Gulf of Mexico. Previously, operations in the Gulf required chartering of commercial boats which grew quite expensive and were limited in flexibility of timing and duration. Drone operations in 2023 found several early morning gradients in ozone which were associated with nocturnal low-level inversions. By sampling repeated vertical profiles through the gradient the early morning development of the boundary layer was observed and the associated changes in temperature, humidity, and ozone could be seen transitioning and mixing before ozone increases were observed, likely due to photochemistry.

Future recommendations following this work include an in-depth analysis of the data collected and summarized here as well as the development of studies to target specific objectives to help address SIP goals. Suggested studies may include convective boundary layer development measurements, commercial marine vessel emission sampling, the acquisition and operation of an economical small ozone lidar from NASA's Jet Propulsion Lab which uses many commercially available parts, and additional photochemistry studies that utilize the unique observational capability of UH's Moody Tower and new ground level lab which will be built and commissioned in 2024.

1. INTRODUCTION

The goals of this project were to collect air quality and supporting measurements in and around the Houston area, Galveston Bay, and adjacent coastal waters in the Gulf of Mexico for four weeks during September 2024. This data should aid the TCEQ in efforts to inform implementation plans to improve air quality in the region.

To collect these data several methodologies were utilized, focusing on the deployment of a mobile laboratory, boat, small uncrewed aerial system (sUAS), also known as a drone, and ozonesondes. This project was built on the TRACER-AQ (2021) and TRACER-AQ2 (2022) campaigns which leveraged NASA and Department of Energy field campaigns, respectively. During the previous two campaigns, the first mobile air quality lab (MAQL1) conducted daytime mobile measurements and the larger MAQL2 trailer was stationed near the San Jacinto Monument near the Houston Ship Channel (HSC). A pontoon boat was operated with selected measurements in Galveston Bay under good conditions and two automated small, instrumented payloads were deployed on commercial boats in the Gulf of Mexico, Galveston Bay, and the Houston Ship Channel.

This project built on these prior projects and deployed a new, larger mobile laboratory, MAQL3, which is capable of housing all the instrumentation from both MAQL1 and MAQL2 with room for additional collaborators and guest researchers. The weather and payload limitations of the pontoon boat were addressed by deploying a new, larger, and more capable boat, MAQL-Sea, which was able to carry an enhanced instrument payload, cover larger areas more quickly, and operate in a wider variety of conditions including into the Gulf of Mexico while increasing crew comfort and therefore safety. The small instrument packages on the commercial boats were operated in 2023 under PGA 582-22-31535-018.

Ozonesondes and drone operations were performed similarly as in prior years however the launches in the Gulf of Mexico were performed from the MAQL-Sea rather than from a chartered boat.

To the pleasant surprise of the project team, the green-paper that was submitted to the NASA Tropospheric Emissions: Monitoring Pollution (TEMPO) satellite team was selected. The project, Coastal Texas Air Quality Observations (CTAQO), requested special observations from TEMPO every 10 minutes for a two-hour period on September 11, 17–19, and 27–28. These special scans had to be selected a week prior to the dates for review and testing before being uploaded to the satellite. Scans roughly included from Lake Charles, LA to the east and west nearly to Bastrop, TX although some periods may have begun as far east as New Orleans, LA, and west to Fredericksburg, TX. The selection of the green-paper was somewhat unexpected since TEMPO was still in the commissioning phase and testing was ongoing. At this stage, the data has yet to be released by NASA.

2. PROJECT DESIGN AND DEPLOYMENT

Although this project was of a smaller scale than both TRACER-AQ and TRACER-AQ2, several concepts remained the same. MAQL3 was based on the TCEQ La Porte site at the La Porte airport where the University of Houston maintains a small support trailer for a NASA Pandora Spectrometer and separate electrical service for field studies, independent of the TCEQ trailer's service. From this location the MAQL3 conducted mobile sampling missions when weather conditions dictated and was not impacted by crew rest or maintenance requirements. The MAQL-Sea carried a more complete suite of instrumentation and was kept in the same slip in the marina in Kemah as the pontoon was previously. This marina, where Clear Lake connects to Galveston Bay, allowed for quick access to the Bay and was just a short distance to the Ship Channel. Several days were also selected for sampling into the Gulf of Mexico under the guidance of an experienced charter captain. This allowed the UH crew to gain valuable training and experience operating in the Gulf while maintaining a high level of safety.

To support this project UH, Baylor, St. Edward's, and Texas A&M collaborated to perform measurements. The following table shows the reported measurements and the university responsible for their operation and subsequent data processing. Texas A&M participated in this project on a volunteer basis to explore the potential mutual benefit of operating their PTR-ToF-MS as part of a larger payload and to determine the suitability of operating the instrument in the MAQL3. Project funds were spent to integrate the instrument into the MAQL3 and to support a Baylor student to operate the instrument in the field, however no funds were provided to Texas A&M for this study.

Table 1. Project instrumentation by measurement platform

Group	MAQL3	MAQL-Sea	Drone	Ground sites
University of Houston	Ozone – Modified Thermo 42C (chemiluminescence)	Ozone – 2B Technology 205	Ozone – En-Sci ECC	
	NO–Air Quality Design custom	NO–Thermo 42i-TL	T/RH/P – InterMet iMet-1-RSB	
	NO_2–Air Quality Design custom	NO_2 – Thermo 42i-TL		
	NOy–Thermo 42C	CO – Teledyne T300U		
	CO–Los Gatos F-CO-23r	SO_2– Thermo 43i-TLE		
	SO_2–Thermo 43i-TLE	$PM_{2.5}$ size distribution – Handix Portable Optical Particle Spectrometer (POPS)		
	Reactive alkenes–Hills Scientific	T/RH/P/WS/WD– Airmar 220WX		
	$PM_{2.5}$ size distribution – Handix Portable Optical Particle Spectrometer (POPS)	jNO2 – Metcon filter radiometer		
	T/RH/P/WS/WD – Airmar WX220	PBL height – Vaisala CL-51		
	jNO2 – Metcon filter radiometer	GPS – Airmar 220WX		
	PBL height – Vaisala CL-31			
	GPS – Airmar 220WX			
Baylor University	$PM_{2.5}$ scattering – TSI 3563	$PM_{2.5}$ scattering – Ecotech Aurora 3000		
	PM2.5 absorption – Brechtel TAP	$PM_{2.5}$ absorption – Brechtel TAP		
	CH4 – Picarro 2307	VOCs – Entanglement Aroma		
		VOCs – resin tube sampler		
St. Edward's University		Ozone vertical profile – En-Sci ECC	Ozone – En-Sci ECC	Ozone vertical profile – En-Sci ECC
		T/RH/P/WS/WD vertical profile – InterMet iMet-4-RSB	T/RH/P – InterMet iMet-1-RSB	T/RH/P/WS/WD vertical profile – InterMet iMet-4-RSB

Upon learning that the TEMPO green-paper was selected UH and TCEQ began adapting the general operating plans to better align with the opportunity provided by enhanced satellite observations. As described previously, an extended command validation and testing window required requested special observation days to be selected a week or more in advance and were chosen through discussions between TCEQ project management, UH, Baylor, and St. Edward's. Fortunately, the selected days aligned quite well with periods of elevated ozone. Normal TEMPO observations will include hourly scans of the daylit portions of most of North America, but these selected days also had a roughly 2-hour window of 10-minute resolution scans. During these windows enhanced measurements occurred, including more frequent ozonesonde launches.

Daily coordination meetings were nominally held each afternoon, except for periods where intensive measurements were not expected for the following day, or the forecast was certain enough not to warrant additional discussion. During these calls students from Baylor not deployed to the field presented a summary of the weather forecast, reducing workloads on PIs and field personnel.

Figure 1 shows an overall summary of the O_3 conditions, campaign measurement activities, and TEMPO special observation days during the intensive measurement campaign.

September HGB Region	1-Sep	2-Sep	3-Sep	4-Sep	5-Sep	6-Sep	7-Sep	8-Sep	9-Sep	10-Sep	11-Sep	12-Sep	13-Sep	14-Sep	15-Sep	16-Sep	17-Sep	18-Sep	19-Sep	20-Sep	21-Sep	22-Sep	23-Sep	24-Sep	25-Sep	26-Sep	27-Sep	28-Sep
HGB High Monitor MDA8 O3	88	82							85	76	97	97	74				83	97	89	72						86	76	80
HGB # Exceedances	25	22							13	1	30	25	3				3	15	13	2						7	5	6
MAQL3 operations																												
MAQL-Sea operations																												
Drone flights																												
HGB Ozonesondes							2	2		4	3						6	4	4								4	5
HGB TEMPO Special Obs																												

Figure 1. Summary of the O_3 *conditions during September 2023.*

More information about each Task and platform is included in the following sections. Appendices at the end of the document contain figures and field notes for their respective tasks.

3. TASKS

3.1 Task 3 - Mobile Air Quality Measurements

3.1.1 MAQL 3 Operations

The MAQL3 is based on a 2018 Crew Cab Freightliner M2 with 24’ lab space. Electrical power is provided by a 20 kW generator which draws from the truck’s 100 gallon fuel tank system. Inlets and meteorological sensors are collocated at the end of a 22’ mast which lays down on the roof during mobile measurements and places the inlets ~2’ in front of the vehicle, helping to reduce the impacts of the vehicle on the measurements. When raised, the mast samples from 33’ above ground. The truck was based on the TCEQ site at the La Porte Airport during this project. At the beginning of the campaign, the power connector for the MAQL3 did not match the receptacle at La Porte. As it was late in the day before this was determined, the MAQL3 opted to return to the UH campus and deploy to the TCEQ/UH site at Aldine the following day. This provided an opportunity to conduct an intercomparison of aerosol measurements with the Aldine BC2 site while changes were made to the power connection in La Porte. As the end of the campaign approached, significant rains were forecast in the Houston area and the project team opted to relocate the MAQL3 to the UH campus to avoid potential issues with soft ground at La Porte as the MAQL3’s turning radius meant that the vehicle tires would be off the gravel road in the turns. Future projects will explore the widening of the turns as well as utilizing the pad installed by the TRACER campaign on the east side of the airport. This pad is much larger and better stabilized than the road to the TCEQ site and has significant power that was left in place and remains available for use. The road approaching the site is also much wider and more clear of telecom lines crossing the road below standard heights.

While waiting out storms on September 25, extensive calibrations were conducted while inside the warehouse. On September 26, in preparation for early morning drives for the coordinated TEMPO observations the truck was preparing to relocate outside for ambient sampling when a melted shore power connector was discovered. This was quickly relayed to the TCEQ project manager, and they were kept informed as the situation evolved. Ultimately the damage to the power cord, power inlet, and some wiring inside MAQL3 required a complete shutdown of the truck to service. This effectively ended the campaign for the MAQL3 a couple of days early, however the boat and sondes were able to continue. Repairs were made and the MAQL3 is once again operational and likely to avoid similar issues as upgraded shore power connectors were used for the repairs.

At the beginning of the project an attempt to make the GPS data more quickly sharable in a dedicated file resulted in GPS data not being logged as anticipated, Impacting September 1-7. Fortunately, many of the affected days were stationary at the Aldine site. The MAQL3 shifted to mobile measurement beginning late morning of September 5 when MAQL3 conducted measurements near the industrial complexes on/around Independence Parkway and in Baytown before driving back to the Aldine BC2 site. On September 6, MAQL3 conducted mobile measurements around the George Bush International Airport, drove to Channelview and La Porte area, and then drove back to the Aldine BC2 site. On September 7, MAQL3 drove down to La Porte then onto Grand Parkway Toll (99), and made several passes on 99, driving by Mount Belvieu up towards northeast of Houston. After several passes the GPS problem was discovered at around 13:15 CST. MAQL3 exited the toll road and got the GPS working before continuing to collect measurements. Two of the three impacted mobile sections, September 5 and 7, have been reconstructed utilizing known locations from time-stamped camera images and Google Earth and Maps.

A summary of the MAQL3 instrumentation can be found in **Table 1** above. Daily figures and field notes are included in Section 6 (Appendix A). Field notes have only been lightly edited for clarity and may still contain typos or jargon. Don't hesitate to get in touch with the project's PI team for clarifications if needed.

3.1.2 Quality Control / Quality Assurance for Mobile Lab Measurements

The sections below describe the results from the quantitative quality assurance processes and calibrations, or the processes applied in the case of qualitative measurements.

3.1.2.1 Inorganic Trace Gases

Calibration of the inorganic trace gases of O_3, NO, NO_2, NOy, CO, and SO_2 were performed using zero air dilution checks at multiple upscale points and a zero-air blank to determine instrument sensitivity factors and verify linearity. These calibrations were performed multiple times during the campaign with more frequent daily span-zero checks done daily before mobile sampling to verify instrument performance and track stability. With the exception of O_3, the blended mixtures were introduced through a valve near the sample inlet with the excess flow venting out the sample inlet itself. The O_3 calibration system is designed to generate O_3 at or near ambient pressure and therefore is difficult to plumb to the sample inlet without introducing significant instrument artifacts due to backpressure in the plumbing. O_3 is therefore calibrated via a solenoid valve near the instrument sample port within the MAQL3 lab space.

Baseline adjustments to NO, NO_2, NOy, and O_3 utilized periodic pre-reactor zeros to determine the baseline on a regular basis. The averages of these zeros were then averaged and interpolated to the original measurement time basis. The resulting interpolated baseline was then subtracted from the measured value prior to applying the sensitivity correction. Other instruments such as the SO_2 had more consistent baselines throughout the project and zero air checks during spans and calibrations were used to evaluate and correct the baseline. Some instruments, such as the CO, have baselines below the LOD and are highly stable so no baseline corrections were applied.

The instrument LODs are calculated by sampling zero air for extended periods, averaged to the final reporting interval, and analyzing the standard deviation of the resulting data. Three times this standard deviation is taken as the LOD for the instrument.

Measurement uncertainties are calculated in quadrature where the combined uncertainty is equal to the square root of the sum of the squares of each known source of uncertainty, expressed as a percentage. For instance, the NO combined uncertainty accounts for the uncertainty in the calibration gas standard, span and zero air mass flow controllers, and the stability of the calibrations conducted throughout the duration of the campaign. Other measurements were calculated similarly with appropriate factors included.

Table 2. *Lower limit of detection for the 10s trace gas data and combined uncertainty for the measurements.*

Measurement	Calibration stability	Lower detection limit (ppbv, 10s averages)	Combined uncertainty
O_3	1.9%	0.44	5.0%
NO	8.6%	0.17	9.8%
NO_2	9.8%	0.12	11.3%
NO_Y	1.9%	0.42	5.0%
CO	3.9%	1.72	6.1%
SO_2	7.7%	1.03	9.0%

3.1.2.2 VOCs

Formaldehyde calibrations were performed using a zero-air dilution calibration similar to the inorganic trace gases. This wet chemistry method also relies on solutions prepared in the lab and periodically requires refilling of the reagent containers which are kept in a small refrigerator inside the instrument rack. To account for slight variations in the solutions as well as the deionized water used to prepare the solutions, zeros were performed daily. Upscale multipoint calibrations were performed nominally weekly after the rubber peristaltic tubing was replaced. Although the tubing can last as long as 10 days, the performance tends to diminish quickly and result in noisier data. Therefore, the decision was made to proactively change the tubing roughly every seven days to ensure that the highest quality data would be assured. Additionally, this timing could be adapted to allow for crew rest periods as needed without sacrificing data quality.

The reactive alkene detector was calibrated with zero-air dilutions like many of the other gas analyzers and utilized both zero-air and pre-reactor zeros to assess the instrument baseline which was corrected in post processing. Unlike the other gas instrumentation, the reactive alkene detector responds to several compounds including propene, ethene, isoprene, and 1,3-butadiene, but does not distinguish between them. As such the instrument was regularly calibrated with propene and the data are corrected using the propene sensitivity and are reported as “propene equivalents” as if the entire plume was comprised of propene. In some situations, it is possible to process the data with sensitivities for other compounds if supporting data indicates that there is evidence to support another compound being the dominant fraction.

The Peak Performer 1 reducing compound photometer instrument was used for isoprene measurement during this project. The instrument was calibrated with an isoprene gas standard and zero-air dilution check at multiple upscale points and a zero-air blank to determine instrument sensitivity factors and verify linearity. These calibrations were performed multiple times during the campaign with more frequent span-zero checks done before mobile sampling to verify instrument performance and track stability. The instrument baseline was corrected in post processing and the data was corrected using the isoprene sensitivity.

Picarro Methane Calibration. The Picarro instrument was calibrated using a multipoint calibration curve that included zero air and known concentrations of methane (calibration methane tank). Methane, for a calibration tank, serves as a proxy gas for HCHO, and can be used in the calibration for both methane and HCHO. The dynamic linear range included ambient background to potent industrial source emission concentrations (0–20 ppm of methane). The Picarro was calibrated on the following dates of September 2023: 3, 5, 6, 8, 9, 10, 11, 14, 17, 18, 19, 21, 23, 25, and 30. An example of the calibration output is below (calibration of September 8, 2023).

G2307 H2CO (Formaldehyde) Surrogate Gas Validation				
Proxy Gas: CH4 (Methane)				
User enters values in light blue cells				
Gas Source	ertified Concentration (relevant unit	bserved Concentration (relevant units)		
Zero Air Primary Gas (ppb)	0.00	0.00		
Zero Air Proxy Gas (ppm)	0.00	0.01		
Proxy #1 (ppm)	2.00	2.08		
Proxy #2 (ppm)	5.00	5.13		
Proxy #3 (ppm)	20.00	20.33		
Required Accuracy (±%)		5		
Validation	Acceptance Criteria	Acceptance	Zero Offset (ppb)	
Zero Air H2CO Concentration	-5 ppb < X < 5 ppb	Pass	0.0	
Validation	Acceptance Criteria	Acceptance		
CH4 Zero validation	-1 ppm < X < 1 ppm	Pass	0.01	
CH4 1 concentrations validation	Offset % < Required Accuracy ab	Pass	4.00	
CH4 2 concentrations validation	Offset % < Required Accuracy ab	Pass	2.60	
CH4 3 concentrations validation	Offset % < Required Accuracy ab	Pass	1.65	Intercept
Span validation using zero air ar	Linearity within required accuracy	Pass	0.977	-0.017
Validation Pass?	All values above are "Pass"	Pass		

Figure 2. Picarro G2307 HCHO instrument calibration on September 8, 2023 using methane at 0, 2. 5, and 20 ppm methane. The calibration resulted in a Pass with an R2 of 0.977 and a y-intercept of –0.017.

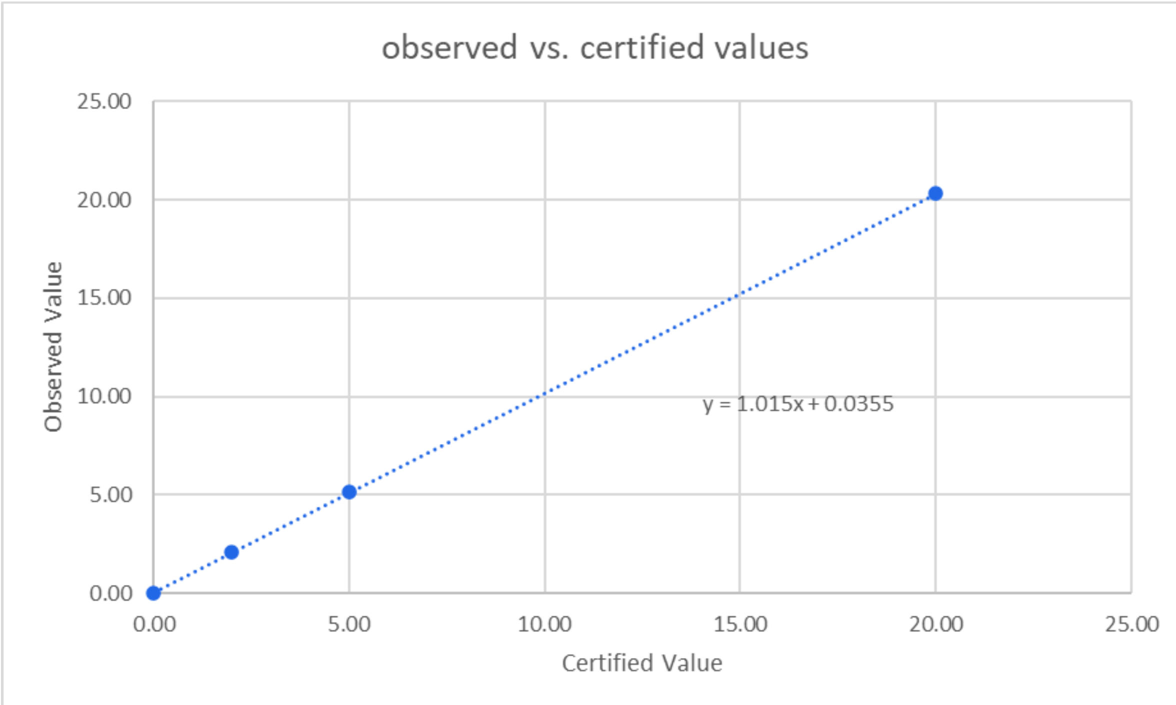


Figure 3. *Example observed vs certified methane comparison associated with a methane calibration.*

The intercomparison between HCHO measurements conducted by Picarro and Aerolaser revealed a strong correlation, with an R-squared value (r^2) of 0.85 and a linear slope of 1.65 (see **Figure 4** below). This significant correlation indicates a robust agreement between the measurements obtained by both instruments, highlighting their reliability and accuracy in quantifying HCHO concentrations. The linear slope of 1.65 suggests that, on average, the Aerolaser measurements were slightly higher compared to those of the Picarro instrument, though this difference remains consistent across varying concentrations. Such intercomparisons are crucial for validating and later comparisons across the two instruments.

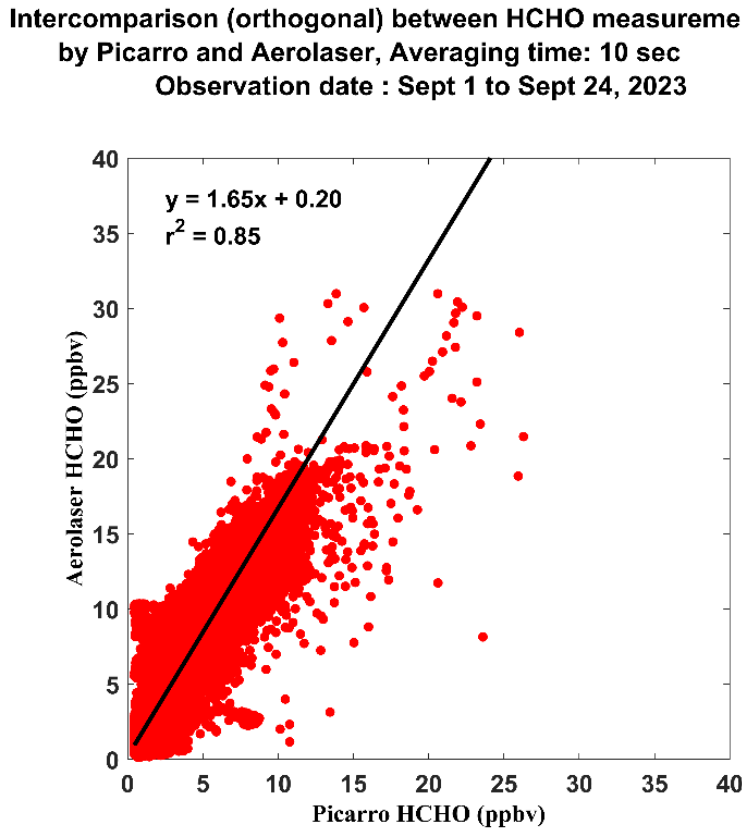


Figure 4. *There were two measurements of formaldehyde on the MAQL3: the Aerolaser, a wet chemistry method, and the Picarro, a cavity ringdown method. The plot above is an orthogonal correlation, which considers the error in the x and y axis, appropriate for an instrument-to-instrument comparison.*

3.1.2.3 Aerosols

Tricolor Absorption Photometer

A 3λ tricolor absorption photometer (TAP; Model 2901, Brechtel Inc., Hayward, CA) measures aerosol light absorption at wavelengths 365 (UV), 528 (green), and 652 (red) nm. TAP uses 10 solenoid valves to cycle through 8 filter spots and 2 reference filter spots. The LED light source simultaneously shines through the sample and reference spots loaded with a 47 mm glass-fiber filter (Brechtel TAP-FIL100). The reference spot allows a measurement by difference approach in the TAP so the increase in light attenuation due to deposited particles on the sample spot is directly compared to the light attenuation of a reference spot. This allows attenuation by collected aerosol to be distinguished from attenuation by the blank filter. The TAP is set to rotate to the next filter spot when a filter spot's transmission reaches the user-set value (Baylor uses 50%), and the reference channel gets altered whenever the sample spot is changed. Each of the 8 sample spots is separated from the other by O-rings that clamp the filter material to prevent any inter-spot leakage. The airflow passes through the filter and into a solenoid valve controlled by the TAP Reader software. Aerosol comparisons with the BC2 network site at Aldine were conducted at the beginning of sampling over the course of several days. Results of the $PM_{2.5}$ absorption and scattering data are shown below.

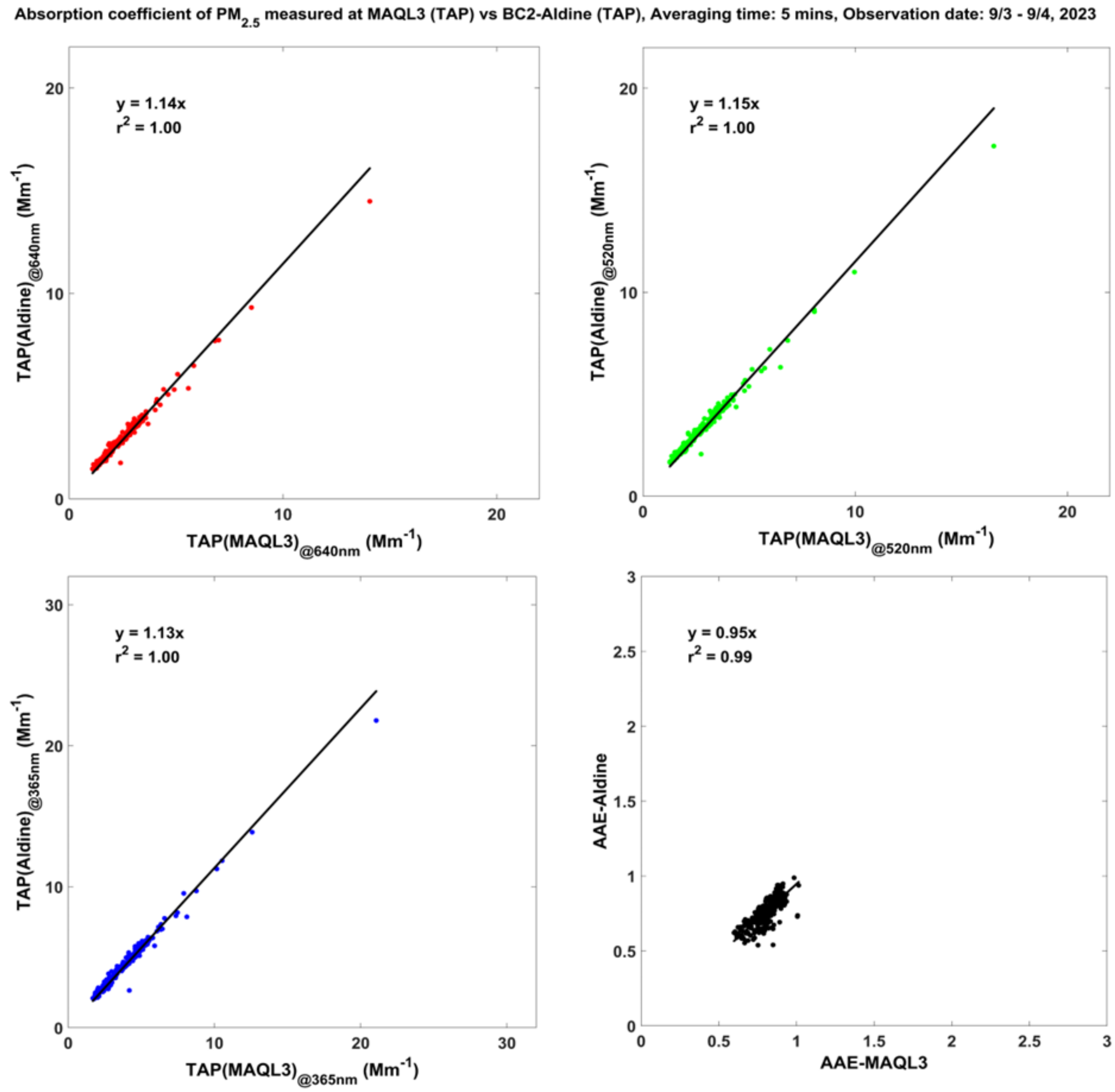


Figure 5. *This figure is an intercomparison between the TAP in the MAQL3 and the TAPS at Aldine, which is a BC2 monitoring network site that does routine measurements of aerosol absorption. The correlation shows good comparison between these two systems, which have co-located, but separate aerosol inlets. The figure includes comparison for red, green and UV wavelength absorption and aerosol Angstrom exponent.*

During this sampling campaign, TAPs measured $PM_{2.5}$ aerosol optical absorption. The TAPs require no calibration other than periodic checks of the air flow meter response. The collocated TAP measurements will be performed for intra-instrument checks. Data corrections will be completed as described previously.

Nephelometer

The light scattering coefficient (σ_{scat}) was measured using an integrating nephelometer (model 3563, TSI Inc., Shoreview, MN) at wavelengths 450, 550, and 700 nm. The measured values were corrected for angular scattering and truncation error (Anderson and Ogren, 1998; Bond et al., 2009) using the relationship: $\sigma_{corrected}$ = correction factor (C) × σ_{neph} where C is the correction factor, σ_{neph} is the scattering coefficient reported by the instrument, and $\sigma_{corrected}$ is the corrected scattering coefficient (Shrestha et al., 2018). During the campaign the TSI nephelometer was calibrated against zero air and CO_2 (Anderson and Ogren, 1998).

Calibration of the integrating nephelometer was performed at least twice during the project. A calibration was performed at the beginning of the project and at the end of the project using a combination of low span level checks and carbon dioxide (CO_2) as the high span level checks. The zero background was checked at the same time as the zeroing of TAPs i.e. when the TAP filter was changed which lasts for 30 minutes.

The Portable Optical Particle Spectrometer (POPS) was periodically zeroed by using a high efficiency particulate air (HEPA) filter to establish a baseline for this instrument. Particle counts recorded by the POPS were very low (averaging <1 total counts/s) during zeros and no baseline correction was applied to the data.

As designed, POPS save data to an SD card and have a limited capacity to transmit data for long periods of time. Therefore, to retrieve POPS data it is necessary to shut down the instrument and remove the SD card to read it on another computer. For lengthy campaigns where data is collected continuously, this method of data retrieval is time-consuming for daily backups and opens many opportunities for data loss due to corruption or other mishaps. Another challenge for operations of this magnitude is that the time in the POPS drifts slightly, so data can become out of sync with other instruments. To sync it with the rest of the platform computers a secure shell protocol (SSH) command must be sent to the POPS periodically. To address the issues with the time and data backups the POPS was connected via USB to another computer. A script was written to first sync the POPS time with the rest of the MAQL3 network, then reboot the POPS, then back up the data files from the SD card each night. Using MobaXterm (an SSH client for Windows), the computer would run the script so that the reboot occurred at midnight each night. The reboot started a new data folder for each day, making it easier to organize files.

3.1.3 Results for Measurements

The following sections showcase overall figures and some selected measurements from the MAQL3 during this campaign. A more complete compilation of the figures and notes from all available days are included in Section 6.

3.1.3.1 Inorganic Trace Gases

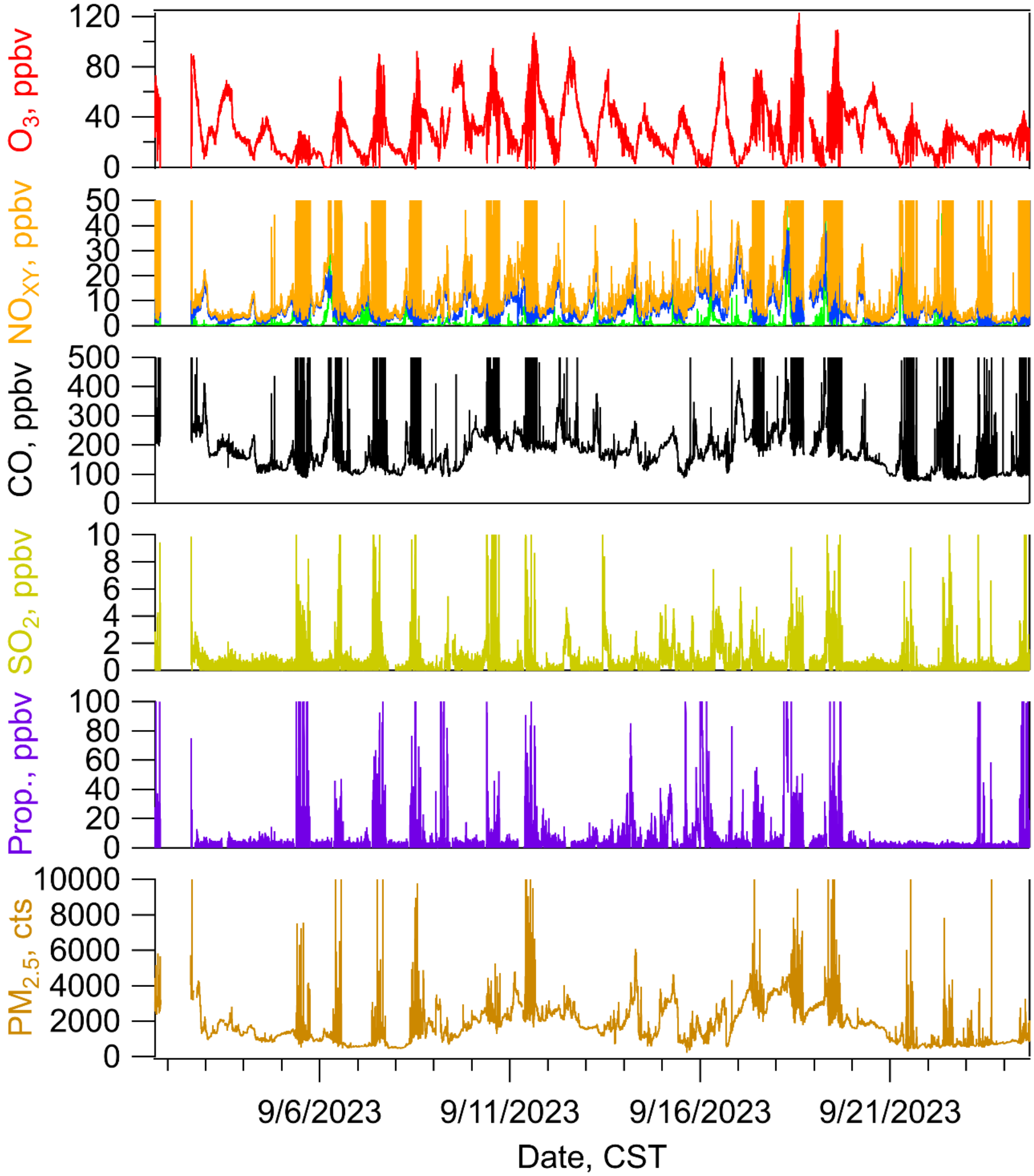


Figure 6. *Measurements made by MAQL3 during the 2023 TCEQ Mobile and Offshore Air Quality Monitoring field campaign. The vertical scaling is set to an appropriate range for the majority of the data. Extreme peaks are truncated in this figure but are present in the associated data files.*

An overall summary of selected trace gas measurements is provided in **Figure 6** above. Stationary measurements were collected at the La Porte airport collocated with the TCEQ site C243. Most mobile measurements were operated from this location and can readily be identified by days where the measurements go off the presented scale as a result of encountering on-road sources such as trucks and cars or operating in close proximity to point and area sources. Additional detailed information is presented for selected cases in the sections below.

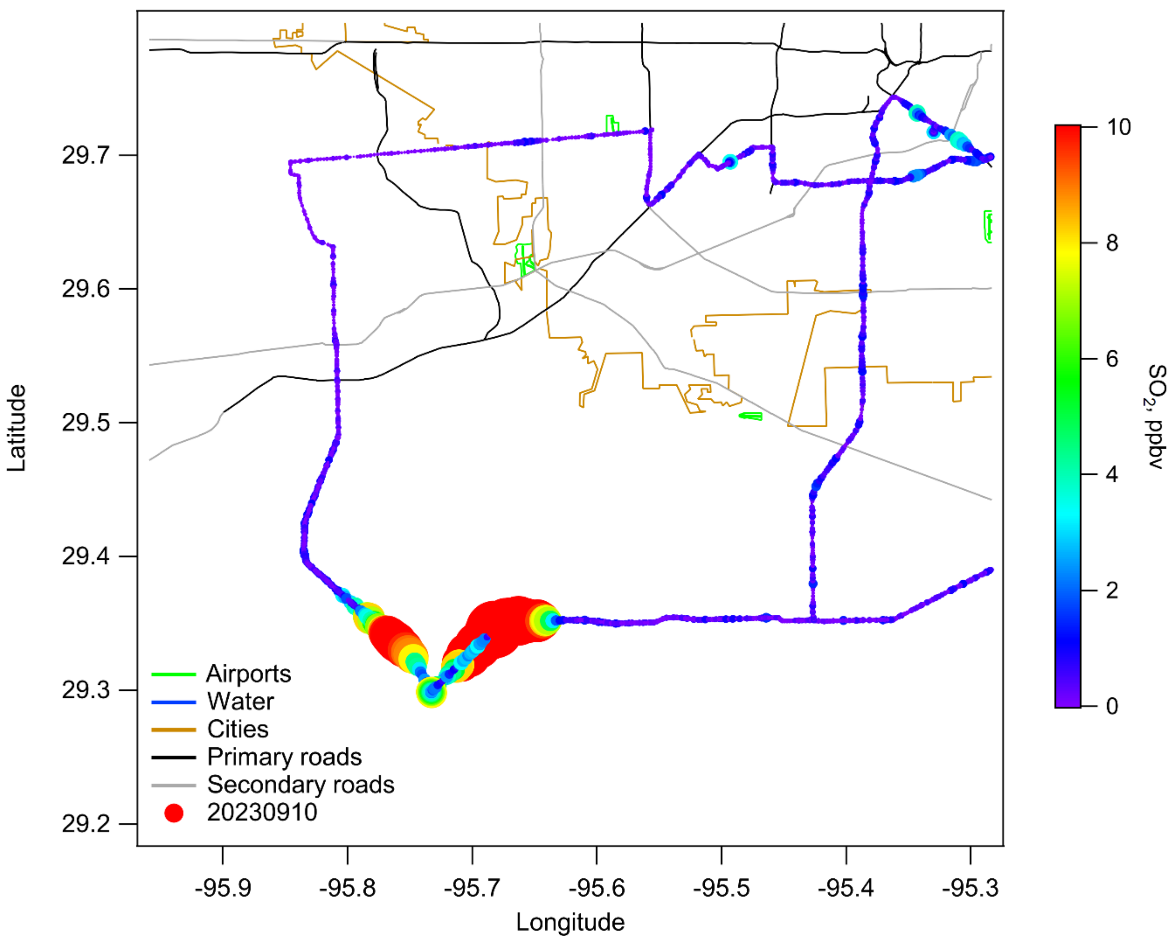


Figure 7. *Spatial plot of MAQL3 SO_2 on September 10, 2024 showing multiple encounters with a plume, likely from the W.A. Parrish power plant. The marker size and color are scaled to the SO_2 measurement.*

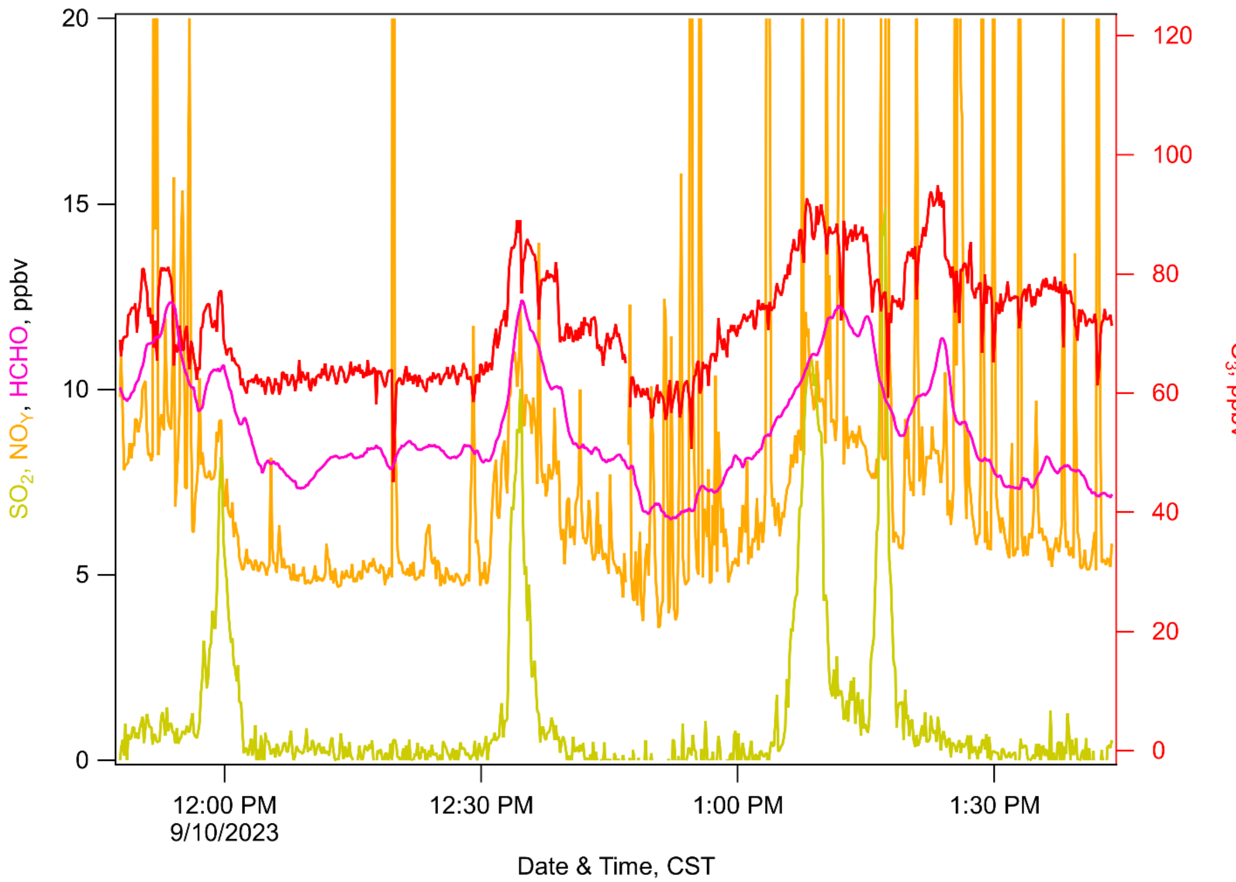


Figure 8. *Time series of some of the SO_2 plume measurements showing enhancements in NO_Y, HCHO, and O_3. The large spikes in the NO_Y data are encounters with other vehicle plumes along the roadway.*

During the campaign, it was not uncommon for the MAQL3 to encounter a SO_2 plume in the vicinity of the Parrish power plant (**Figure 7**). If the plume was not also potentially blended with other plumes, such as the suspected Houston urban plume, it was occasionally possible to find elevated NO_Y, HCHO, and O_3 as seen in **Figure 8**. In this example, the plume just after 12:30 PM CST shows as much as a 25 ppbv increase in observed O_3 (from 63 to 89 ppbv), 10 ppbv of SO_2, 7 ppbv of NO_Y, and 4 ppbv of HCHO. Similar encounters with the suspected Parrish power plant plume have been seen in recent years during the TRACER-AQ and TRACER-AQ2 measurement campaigns.

3.1.3.2 VOCs

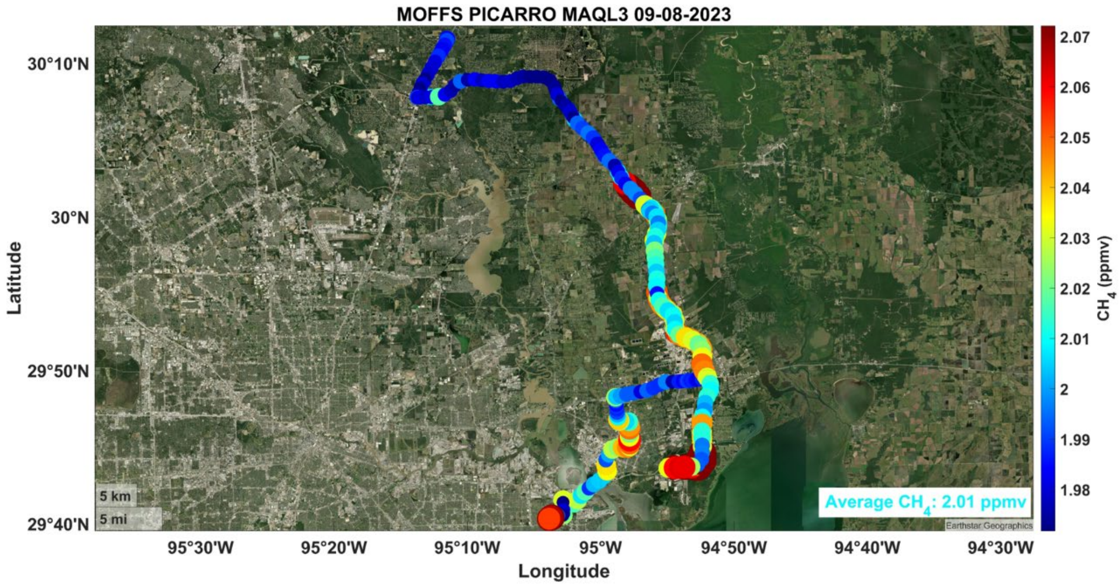


Figure 9. *MAQL 3 mobile transect of Picarro methane concentrations (ppmv) for 09-08-2023.*

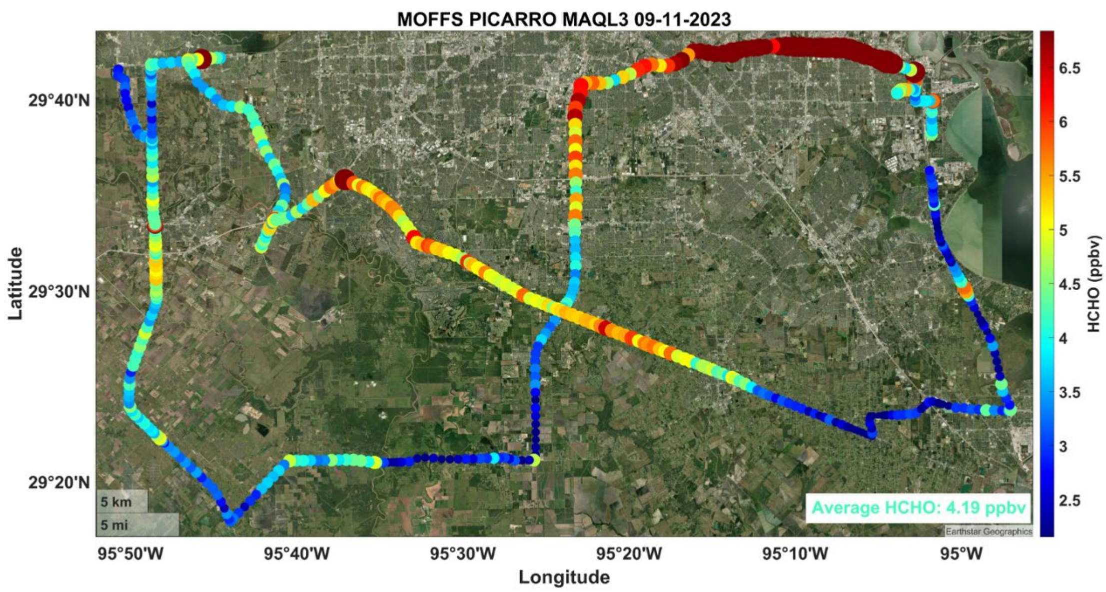


Figure 10. *MAQL 3 mobile transect of Picarro HCHO concentrations (ppbv) for 09-11-2023.*

Mobile MAQL 3 transects through rural to industrial areas have highlighted significant variations in HCHO concentrations compared to background levels (**Figure 10**). Background atmospheric concentrations of HCHO typically range from about 0.5 to 2 ppbv in clean, rural environments. However, measurements taken in industrial zones using MAQL 3 have indicated substantially higher levels exceeding 6.5 ppbv, demonstrating the impact of industrial activities on air quality. These elevated concentrations may be associated with emissions from industrial processes, chemical production, and other sources of VOCs.

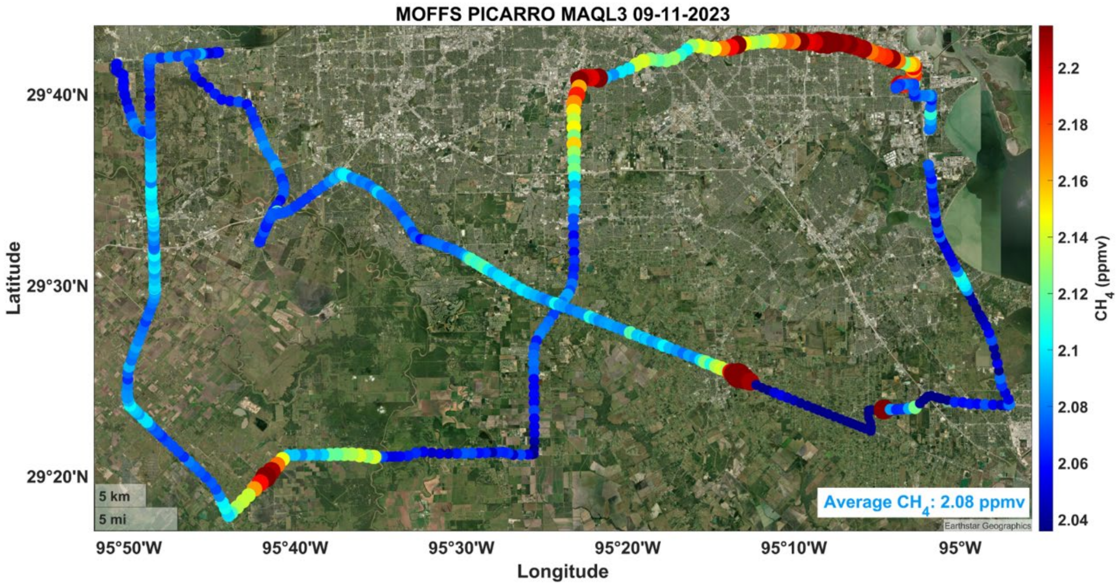


Figure 11. *MAQL 3 mobile transect of Picarro methane concentrations (ppmv) for 09-11-2023.*

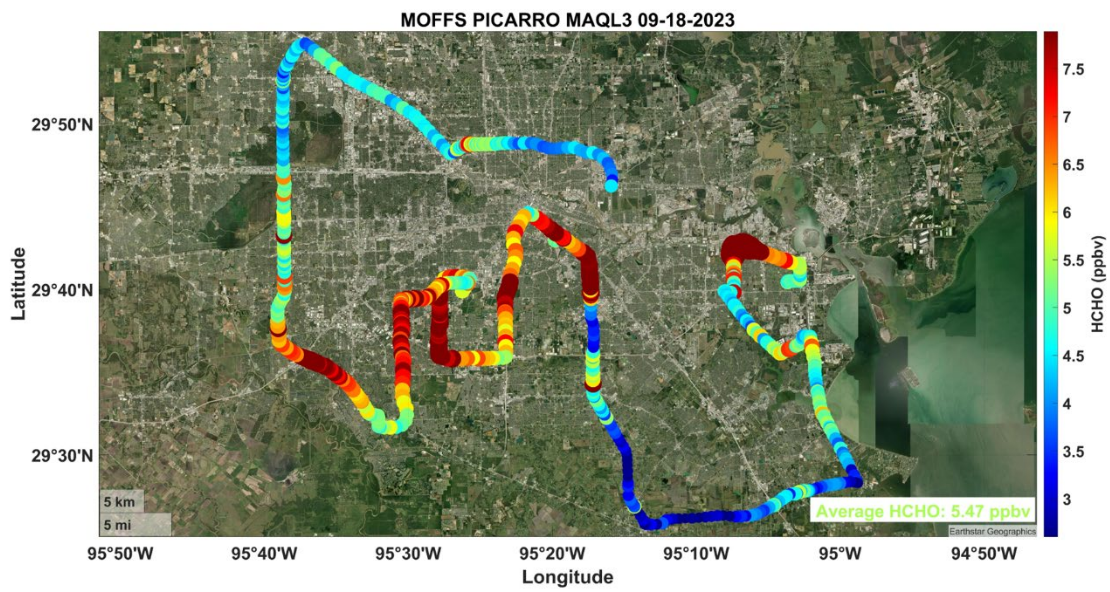


Figure 12. *MAQL 3 mobile transect of Picarro HCHO concentrations (ppbv) for 09-18-2023.*

On September 18, 2023, a transect sampling strategy was employed to characterize a potential HCHO plume that exceeded 7.5 parts per billion (ppb) and appeared to be transported across the city by slow easterly winds (La Porte airport 10 a.m. to 3 p.m., 5 to 8 mph; see **Figure 12**). Transect sampling involves driving along specific routes across the city, systematically focusing on locations within and around the plume. Here MAQL 3 was able to map out the spatial extent of the HCHO plume. It is interesting that methane was also high near the industrial area (near the ship channel) but did not persist along the HCHO transect. This is interesting because HCHO typically is thought of as having a short atmospheric half-live as compared to methane, **Figure 13**.

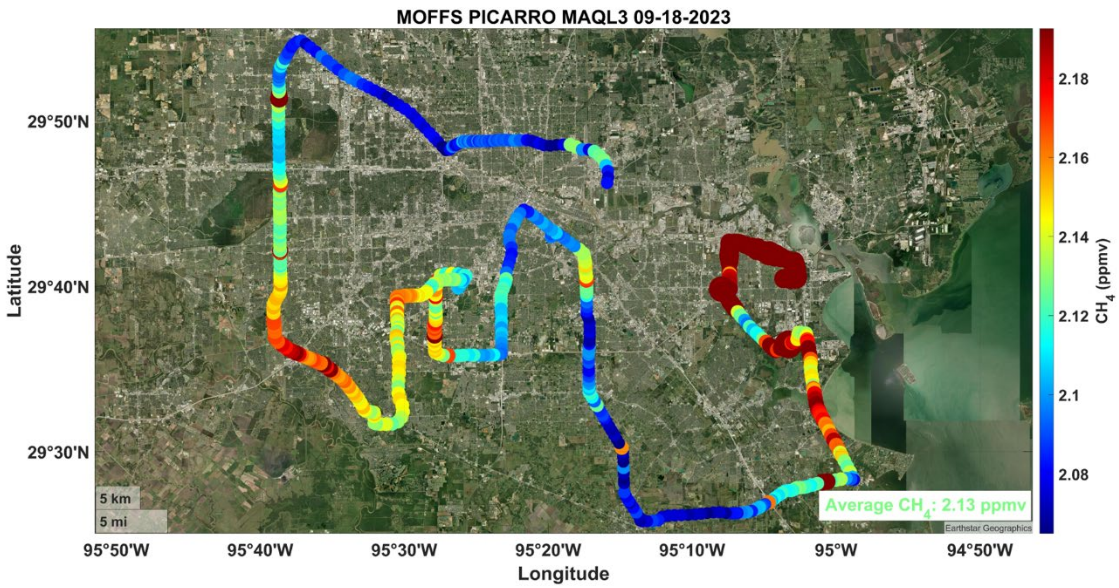


Figure 13. *MAQL 3 mobile transect of Picarro methane concentrations (ppmv) for 09-18-2023.*

3.1.3.3 September 18, 2024 – Elevated HCHO and reactive alkenes

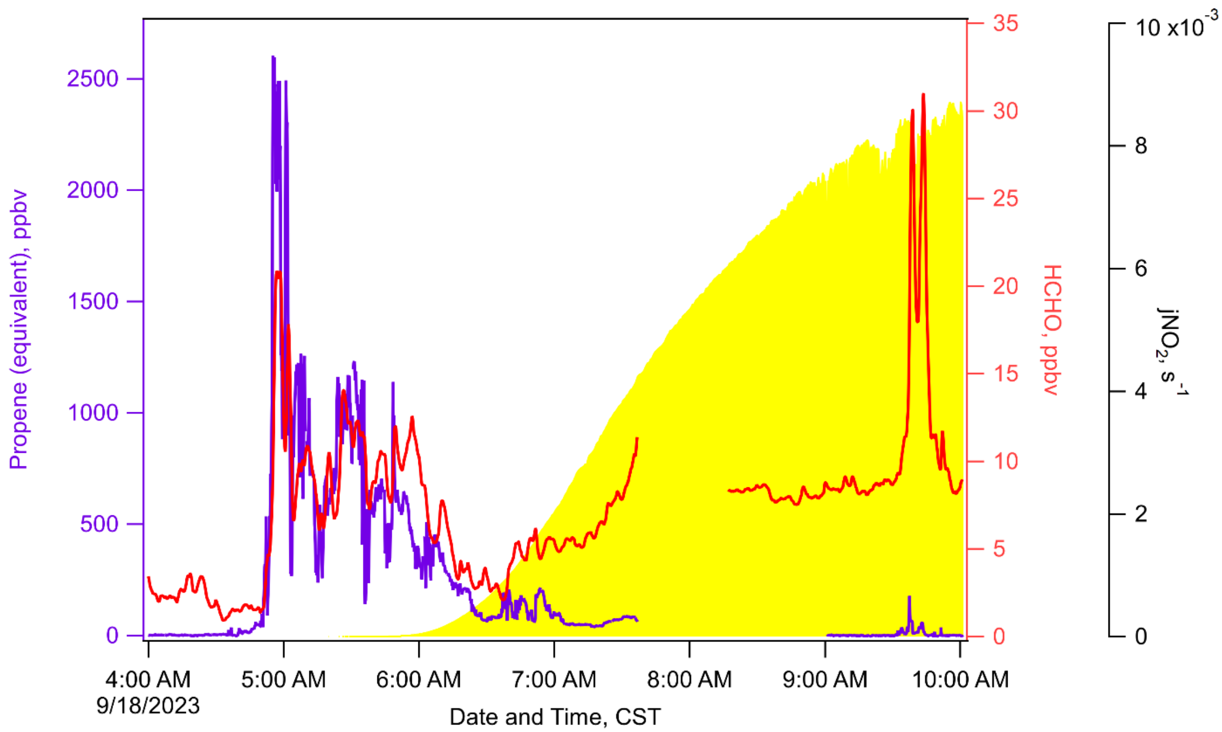


Figure 14. *Time series of reactive alkenes (propene equivalent), HCHO, and jNO_2 while parked at La Porte in the early morning before going mobile at 9:18 a.m.*

During the early morning period of September 18 (~4:30–7:30 CST) the MAQL3 observed a large plume of reactive alkenes which when reported as propene equivalents (the instrument does not speciate between HRVOCs and has a different sensitivity to each compound) peaked over 2,500 ppbv and remained elevated until morning calibrations began prior to driving. This plume also contained significant levels of HCHO which were strongly correlated with the alkene signal, peaking around 20 ppbv at 5:00 CST. While the alkene and HCHO plumes showed similar trends before sunrise, after sunrise (6:08 CST) the HCHO began to increase, diverging from the pattern seen in the earlier hours, **Figure 14**.

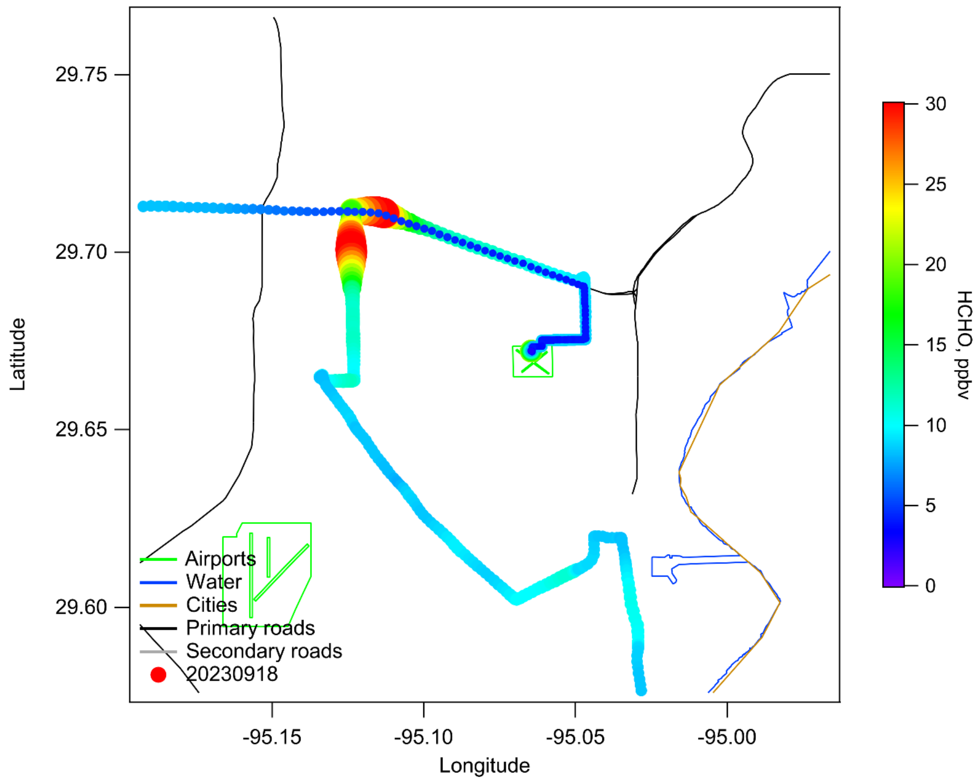


Figure 15. *Spatial plot of MAQL3 track colored and sized by HCHO for September 18, 2023.*

After leaving the La Porte airport the MAQL3 again encountered a significant HCHO plume, in excess of 30 ppbv at times, along the access road of Highway 225 shortly after 9:30 CST, **Figure 15**. After crossing through the peak, the MAQL3 turned south on Center St. and found another peak, both of which were correlated with alkenes, although levels were in the 50–70 ppbv range for the majority of these plumes. The route was completed but did not encounter another large peak.

A preliminary search of the TCEQ emission event database did not show any events that appeared to be related to these observations. It should be noted that previous measurements have shown similar relationships between large alkene and HCHO plumes in the night or early mornings. Other nights in September 2023 showed elevated alkene plumes, sometimes for several hours, but tended to be in the 10s to 100s of ppbv and did not appear to have similarly enhanced HCHO levels before sunrise.

Fifteen monitors in the Houston area reported an MDA8 above 70 ppbv, with the highest reporting 97 ppbv (C53 Bayland Park).

3.1.3.4 Aerosols

MAQL 3 mobile aerosol data transects for select days (September 08, 11, and 18, 2023). Select aerosol data is highlighted in the figures below and included Absorption Ångström Exponents (AAE), Scattering Ångström Exponents (SAE), and equivalent black carbon (eBC). The mobile absorption (three wavelengths) and scattering (three wavelengths) coefficients are not presented, however, the campaign timeseries for the aerosol absorption coefficients, scattering coefficients, AAE, eBC, and SAE are presented below in **Figure 16**–**Figure 18**. **Figure 19**–**Figure 21** focus on September 8, **Figure 22**–**Figure 24** highlight September 11, and **Figure 25**–**Figure 27** show data from September 18. It is important to note that eBC is the mass concentration of black carbon and that these measurements can help identify the contribution or areas of combustion-related sources (e.g., burning fossil fuels including vehicular exhaust) to the overall aerosol composition. High concentrations of eBC are often associated with poor air quality. These combustion-related sources should also support in an AAE near 1 (i.e. strong wavelength dependency) and suggest a BC-dominated aerosol.

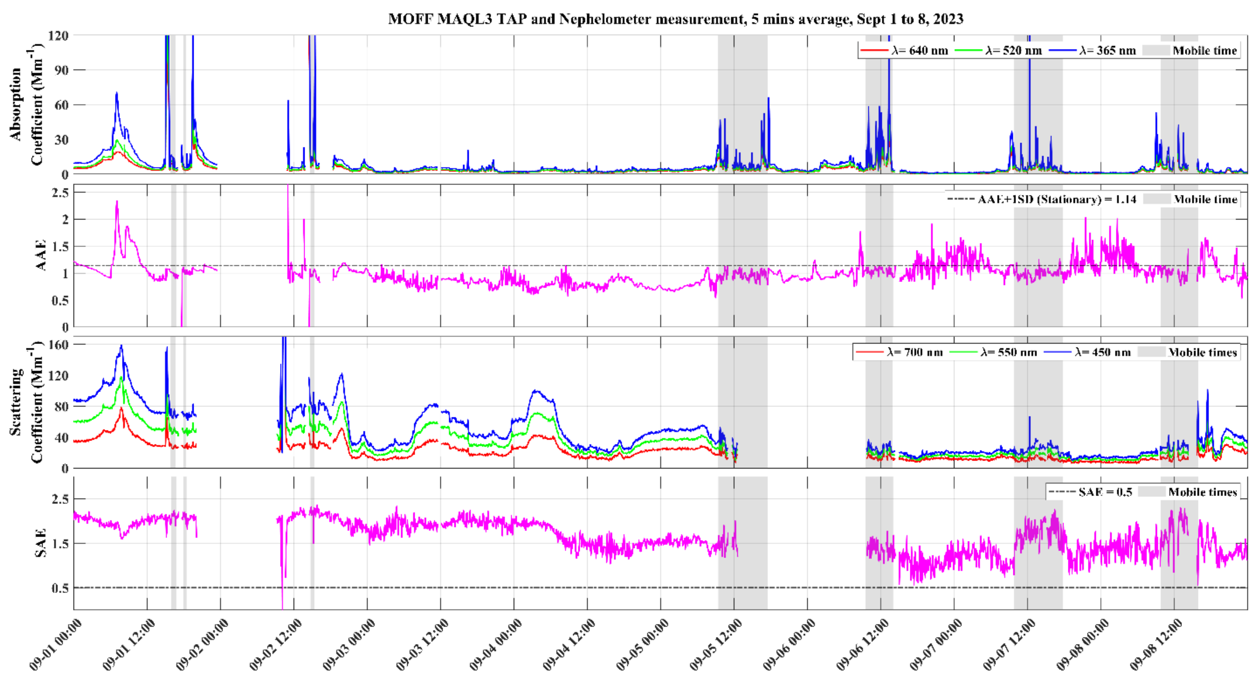


__Figure 16.__ MAQL 3 campaign timeseries for aerosol absorption coefficients, scattering coefficients, AAE, and SAE for September 1–8, 2023. Grey periods indicate mobile transects.

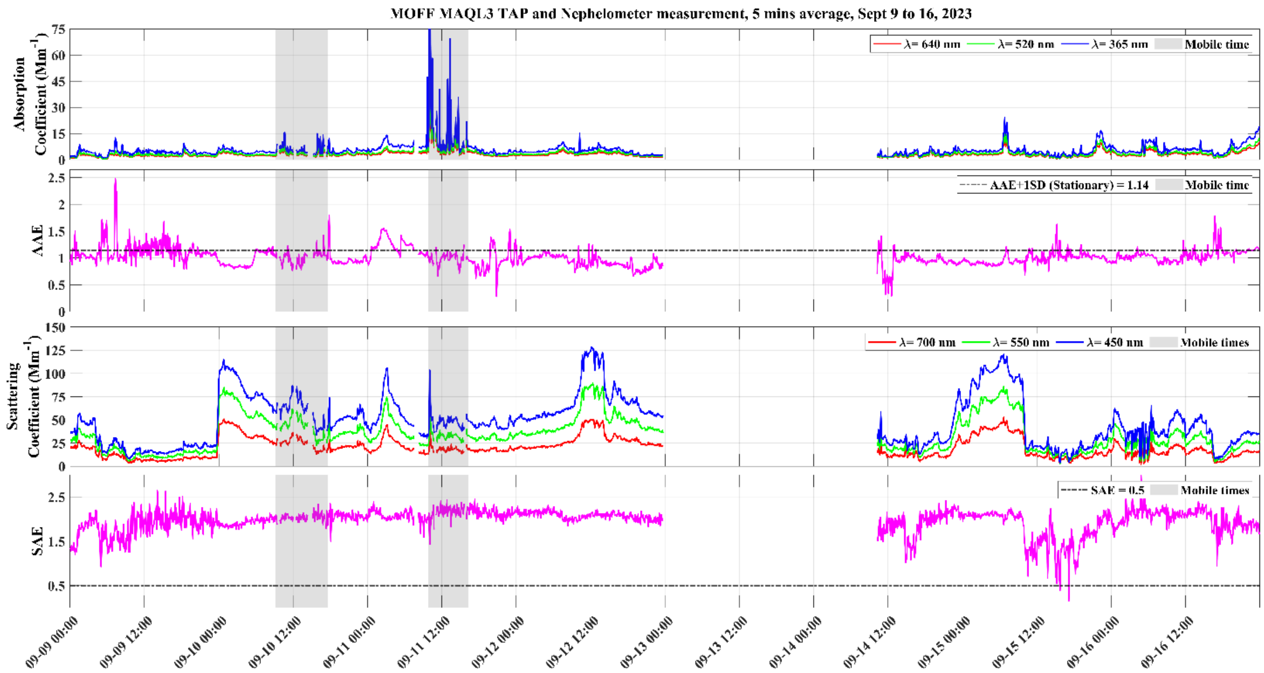


Figure 17. *MAQL 3 campaign timeseries for aerosol absorption coefficients, scattering coefficients, AAE, and SAE for September 9–16, 2023. Grey periods indicate mobile transects.*

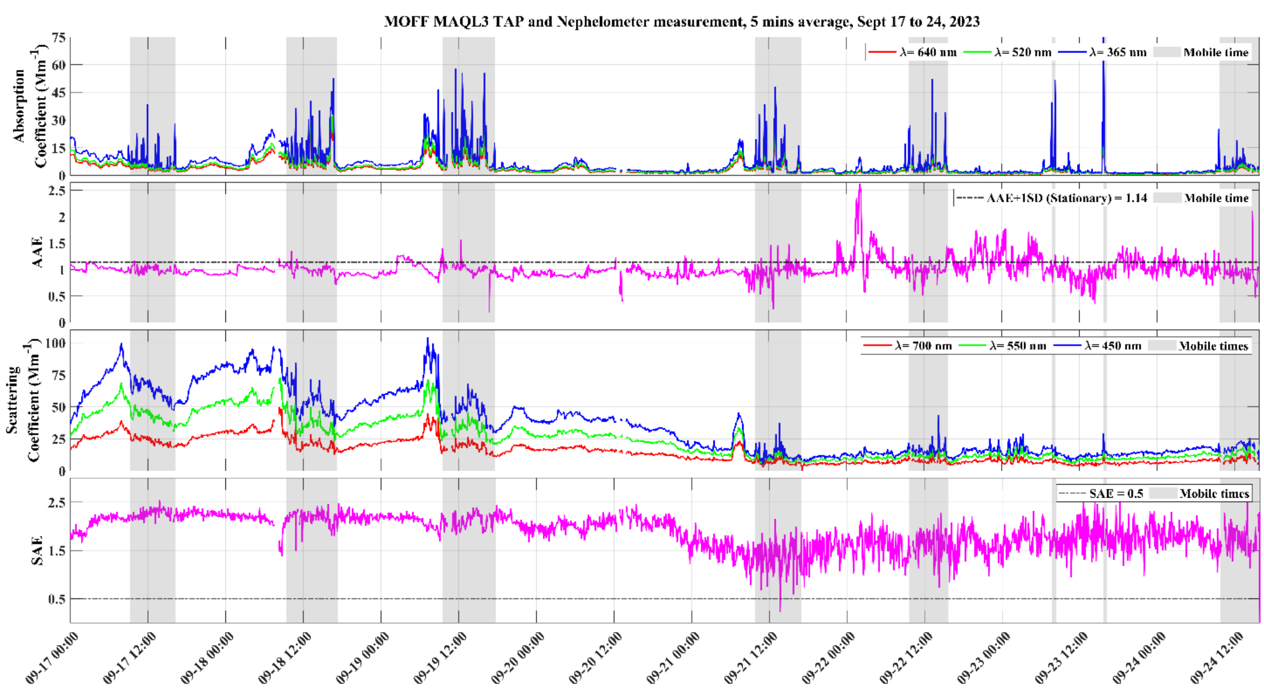


Figure 18. *MAQL 3 campaign timeseries for aerosol absorption coefficients, scattering coefficients, AAE, and SAE for September 17–24, 2023. Grey periods indicate mobile transects.*

September 8, 2023

Figure 19. *MAQL 3 mobile transect of TAP eBC at 520nm for September 8, 2023.*

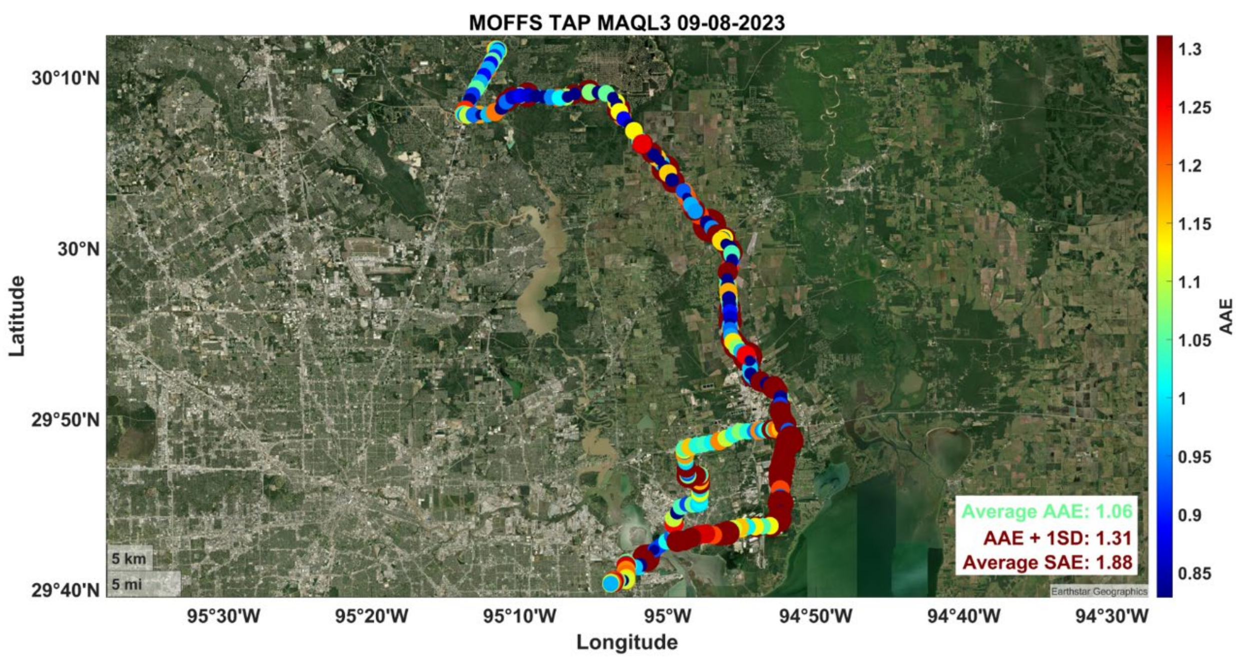


Figure 20. *MAQL 3 mobile transect of TAP AAE calculations for September 8, 2023.*

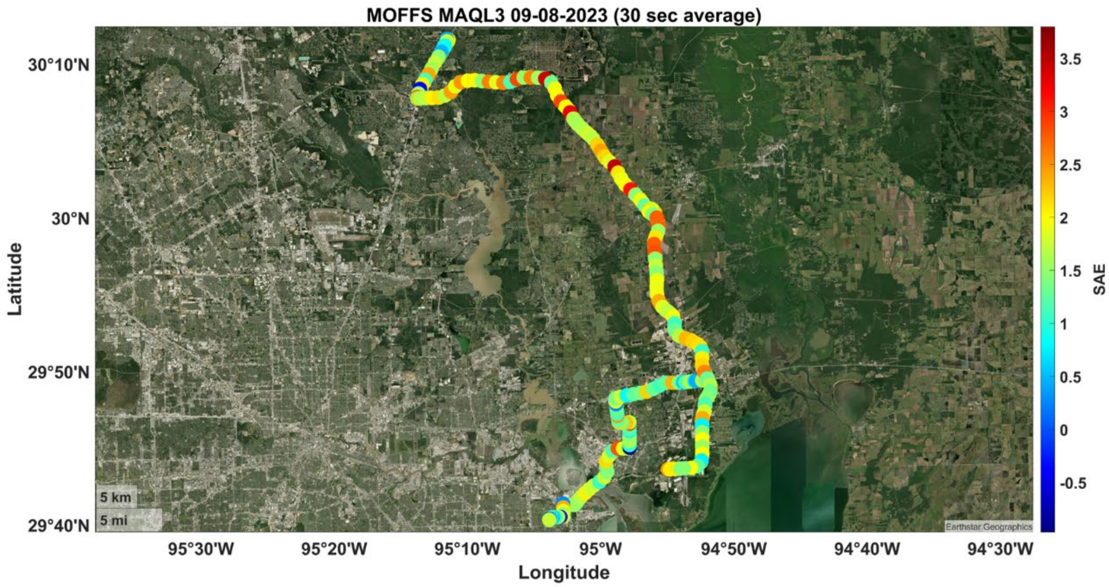


***Figure 21.** MAQL 3 mobile transect of Nephelometer SAE calculations for September 8, 2023.*

<u>*September 11, 2023*</u>

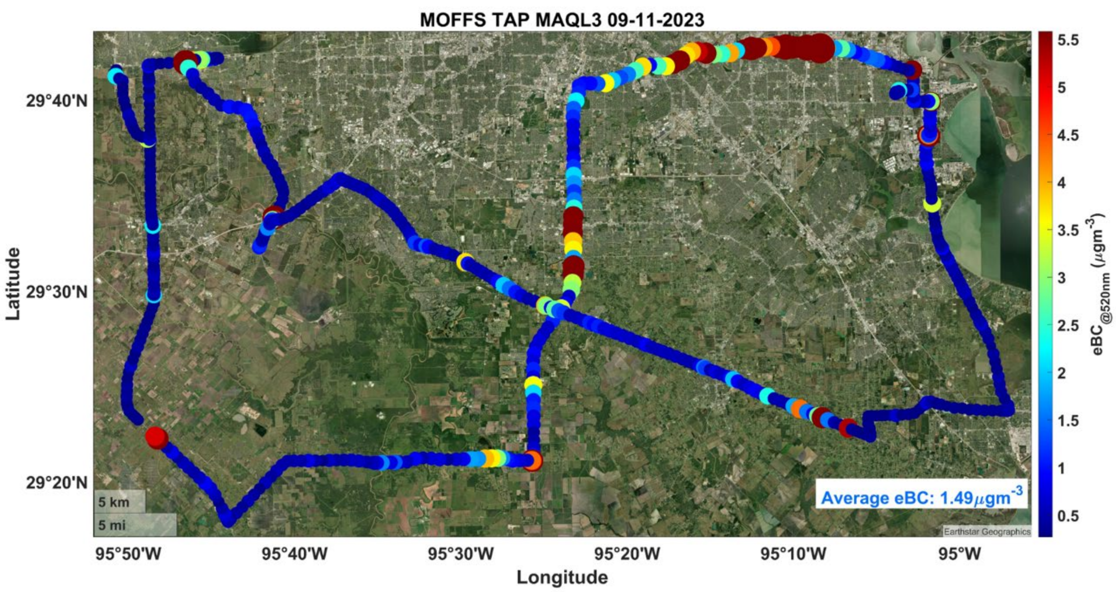


Figure 22. MAQL 3 mobile transect of TAP eBC at 520nm for September 11, 2023.

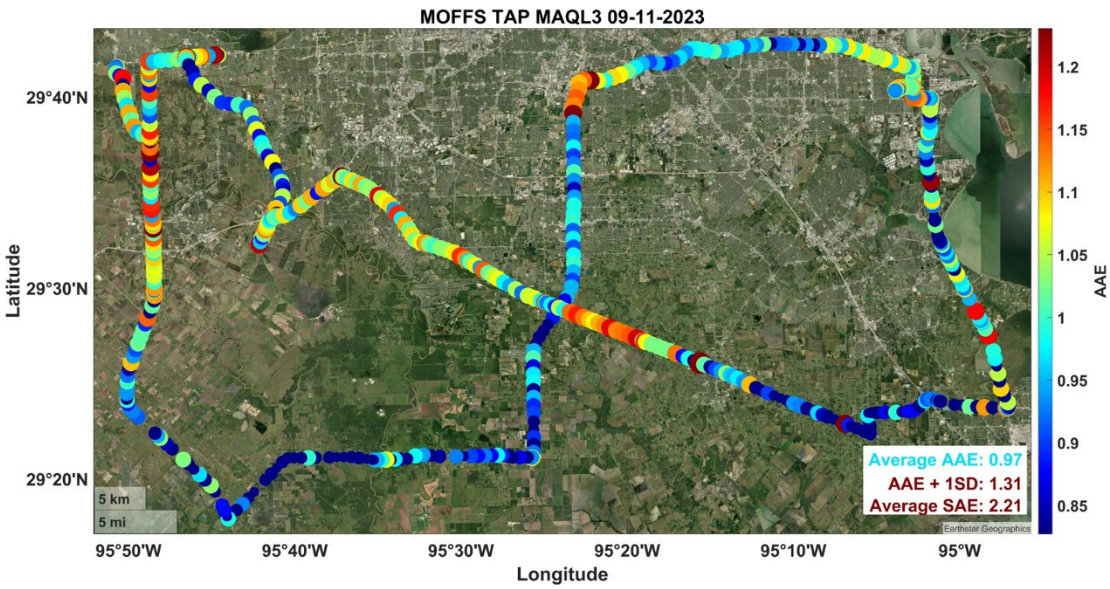


Figure 23. *MAQL 3 mobile transect of TAP AAE calculations for September 11, 2023.*

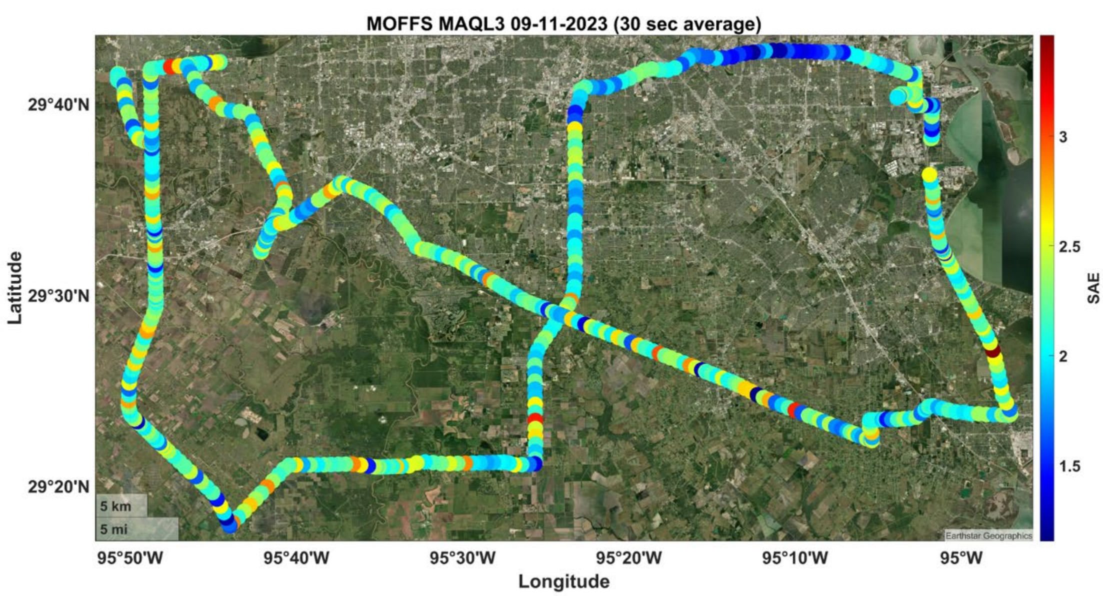


Figure 24. *MAQL 3 mobile transect of Nephelometer SAE calculations for September 11, 2023.*

The lower SAE near industrial zones (SAE near 1.5, **Figure 24**) suggests smaller particles as compared to most of the transect, which were near 2.0 to 2.5 and suggests more light-scattering aerosol particles (e.g., sulfate containing particles). As the MAQL extends across the city and to more rural areas, the higher SAE values indicate a shift towards larger aerosol particles or a different aerosol mix, potentially influenced by urban pollution sources such as traffic emissions and secondary aerosol formation.

<u>*September 18, 2023*</u>

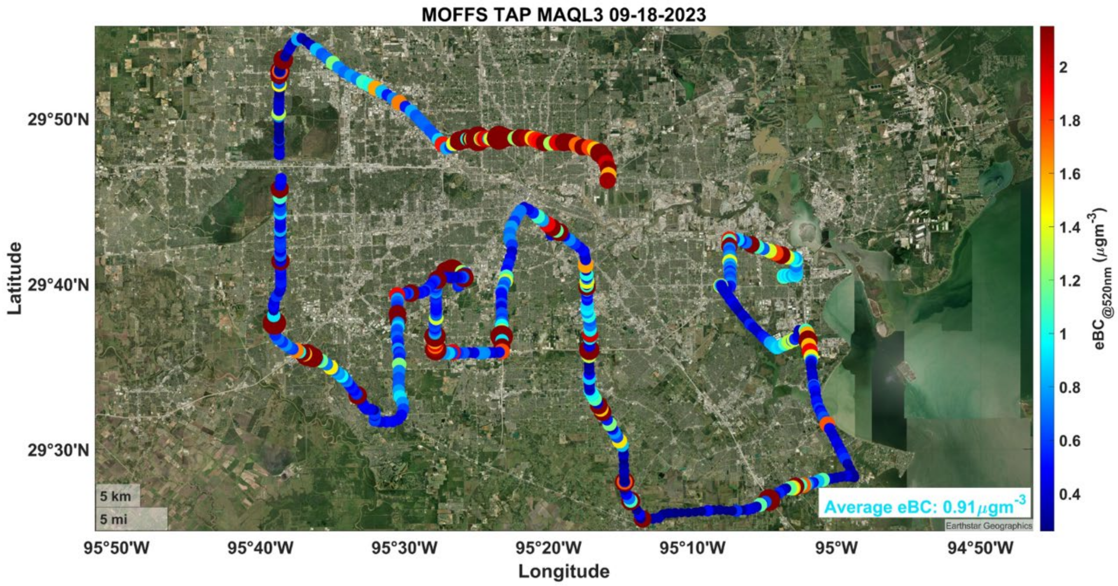


Figure 25. *MAQL 3 mobile transect of TAP eBC @ 520nm calculations for September 18, 2023.*

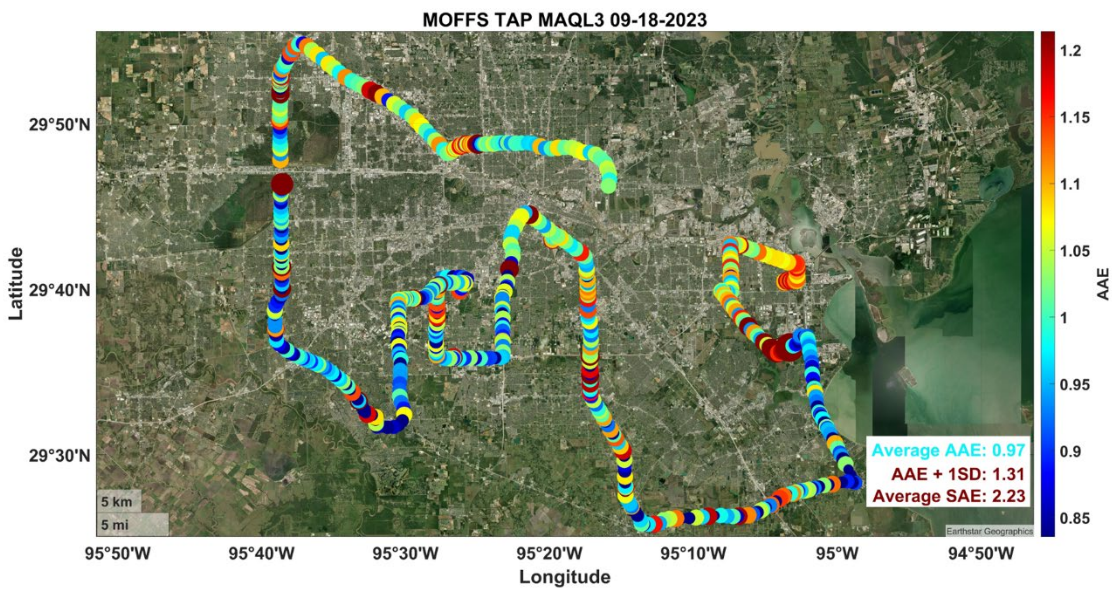


Figure 26. *MAQL 3 mobile transect of TAP AAE calculations for September 18, 2023.*

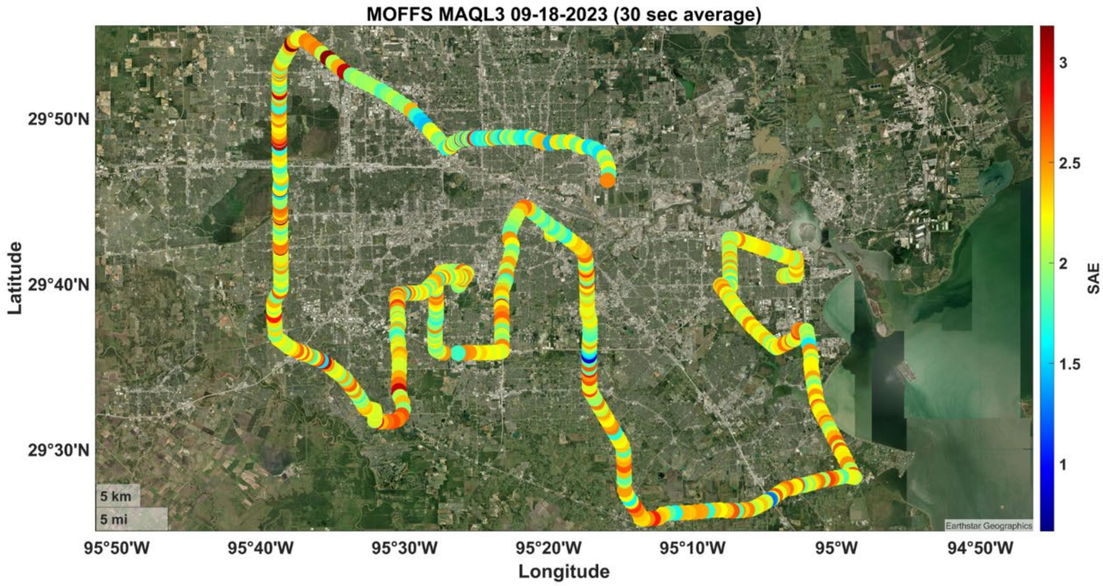


Figure 27. *MAQL 3 mobile transect of Nephelometer SAE calculations for September 18, 2023.*

3.2 Task 4 – Offshore Air Quality Measurements

3.2.1 MAQL-Sea Operations

The Mobile Air Quality Lab Sea (MAQL-Sea) boat was initially deployed on 14 August 2023 to begin the engine break-in process on the new Suzuki outboard engines that were installed in June 2023. After the initial break-in process the boat was pulled from the water for the first engine service and to raise the protective bottom paint to accommodate the new waterline due to the increased instrument and personnel payload onboard during operations. The MAQL-Sea was returned to the water on 1 September 2023 and first deployed to Galveston Bay on 6 September 2023. During the 4-week campaign there were 14 days of mobile operations, including 3 days when the MAQL-Sea operated offshore in the Gulf of Mexico. Typically, the MAQL-Sea would begin mobile operations at 08:00 CST and return to the dock at approximately 15:00 CST (**Figure 28**). Under certain conditions it is possible to coordinate sampling between the MAQL-Sea and MAQL3. This was demonstrated on one occasion while sampling in the Channelview area where MAQL-Sea was able to safely navigate in a heavy barge traffic area upwind of a facility while MAQL3 sampled downwind on selected roads.

September	1-Sep	2-Sep	3-Sep	4-Sep	5-Sep	6-Sep	7-Sep	8-Sep	9-Sep	10-Sep	11-Sep	12-Sep	13-Sep	14-Sep	15-Sep	16-Sep	17-Sep	18-Sep	19-Sep	20-Sep	21-Sep	22-Sep	23-Sep	24-Sep	25-Sep	26-Sep	27-Sep	28-Sep	29-Sep	30-Sep
High Monitor	88	80	65			65	65	68	85	76	97	97	74			65	83	97	89	72	57	56	55	58		86	76	80	59	
# Exceedances	25	22							13	1	30	25	3				3	15	13	2						7	5	6		
MAQL Sea																	*	*	*											

Figure 28. *Operational days for the MAQL-Sea boat platform along with the ozone AQI rating, high MDA8 ozone value and the number of region 12 exceedances for September 2023.*

The MAQL-Sea boat sampling platform was equipped with instrumentation inside the cabin of the boat as well as mounted to the roof using a system of aircraft seat track mounted to the floor and ceiling and utilizing mounting accessories designed to be secured in the track system (**Figure 29** and **Figure 30**).

Figure 29. *MAQL-Sea boat sampling platform docked at the Seabrook Marina and Shipyard September 2023.*

Figure 30. *MAQL- Sea instrumentation rack mounted and secured inside of the cabin on aircraft seat track.*

3.2.2 Quality Control / Quality Assurance for Offshore Air Quality Measurements

3.2.2.1 Inorganic Trace Gases

The inorganic trace gas instrumentation was calibrated in the same fashion as in MAQL3 described in section 3.1.2.1 above with the exception that the valve to introduce the dilution mixtures to the inlet was manual and accessed from the bow while secured in the marina. The following table describes the instrument calibration stability, lower limit of detection, and overall combined uncertainty.

Table 3. *Lower detection limit for the 10s trace gas data and combined uncertainty.*

Measurement	Calibration stability	Lower detection limit (ppbv, 10s averages)	Combined uncertainty
O_3	3.8%	5.06	4.9%
NO	2.8%	0.55	4.1%
NO_2	2.9%	1.10	6.6%
CO	4.5%	20.3	5.4%
SO_2	2.5%	1.54	4.2%

3.2.2.2 VOCs – (AROMA + Resin Tubes)

AROMA VOC Analyzer

The cavity ring down instrument can be operated in two modes: rapidscan and Labscan. Rapidscan is a direct spectroscopy technique and is typically providing measurements at 5 seconds. The Labscan is a direct spectroscopy technique with a thermal desorption separation prior to analysis with samples at 10-minute intervals. Because both modes utilize cavity ring down spectroscopy (CRDS), where a laser is pulsed into an optical cavity or space between two mirrors, the calibration is the same. The CRDS was calibrated before and after the campaign. The calibration is verified periodically during the campaign, for example during the daily startup procedure. For specific VOCs the AROMA was also calibrated using a standard gas mixture with known VOC concentrations.

Resin Tubes

VOC sample collection via sorbent tubes followed by thermal desorption-gas chromatography-mass spectrometry analysis is a well-established approach. Stainless steel tubes are small, typically 9 cm in length and 0.64 cm in diameter, and contain sorbents of varying affinities that retain a wide range of compounds (i.e., C4 –C32). Ambient air was drawn through the tubes at a rate of 0.1 L/min for 10 minutes, and the volatile species were captured on the sorbents. The samples were transported back to Baylor University in a double-walled, chilled container for chemical analysis and placed in cold storage (< 5 °C) for up to two weeks. Briefly, VOCs were desorbed from tubes during an initial heating stage at 250 °C and held for eight minutes under a constant helium flow at 1 ml/min. VOC samples were transferred along a 150 °C flow path to a cold trap held at 20 °C where they were refocused before the chromatographic separation. As the cold trap was heated, the desorbed sample was sent to the analytical column (DB-624 (60 m x 0.32 mm ID x 1.8 µm), J&W Scientific, CA, USA) which was heated from 40 °C to 255 °C before quantification using the MS/MS (chemical analysis runtime: 36 min).

Targeted chemical analysis was conducted via a calibration curve across a range of 10 ppb to 2 ppm. The TD-GC-MS/MS system was calibrated before sample batches using liquid analytical-grade chemical standards under a flow of 0.5 ml/min of nitrogen for five minutes. Calibration tubes contained the same sorbents as field samples and were analyzed using the same thermal desorption and chemical separation methods. The calibration curve linearity (R^2 value) for all target species was > 0.97. Quality assurance and quality control were monitored during sample analysis by running a continuing calibration verification (CCV) standard solution at regular intervals (approximately every 4th injection). CCV standard solutions included all analytes at the middle point of the calibration curve. Analytes recoveries beyond ± 40% from CCV analyses required a new calibration curve to be run. A list of the target analytes collected by resin tubes and analyzed by the TD-GC-MS/MS is included in **Table 4**.

Table 4. *Resin tube target analyte list for the TD-GC-MS/MS analysis.*

Target Analyte	**Retention Time (min)**	**Ions (m/z)**	**Dynamic Linear Range**		**Potential Sources**
			Lower Limit (pg/uL)	Upper Limit (ng/uL)	
Benzene	9.45	52, 50, 77	13	100	Transportation emissions
Toluene	13.18	91, 39, 65	13	100	
Ethylbenzene	15.95	91, 65, 39	13	100	
m-& *p*-Xylene	16.16	91, 65, 77	13	100	
o-Xylene	16.85	91, 65, 39	13	100	
Isoprene*	5.07	67, 41, 65	14	9	Biogenic emissions
α-Pinene*	17.46	77, 51, 9	13	8	
β-Pinene*	18.64	77, 51,9	13	8	
Limonene*	19.48	67, 77, 91	13	8	Cleaning & personal care products
D4-Siloxane	18.06	249, 73, 205	20	12	
Benzyl alcohol	20.39	77, 79, 107	13	8	
D5-Siloxane	20.5	250, 179, 267	20	13	
Texanol	23.45	56, 71, 41	20	13	
PCBTF	15.79	145, 130, 161	11	7	Industrial emissions
Styrene	16.91	78, 77, 103	19	12	

3.2.2.3 <u>Aerosols</u>

The Portable Optical Particle Spectrometer (POPS) on the MAQL-Sea boat was periodically zeroed by using a high-efficiency particulate air (HEPA) filter to establish a baseline for this instrument. Particle counts recorded by the POPS were very low (averaging <4 total counts/s) during zeros and no baseline correction was applied to the data. The same script that was used for the MAQL3 POPS was used on the Osprey for time-syncs and data backups (see section 3.1.2.3).

3.2.3 Results for Measurements

3.2.3.1 Meteorological and Inorganic Trace Gases

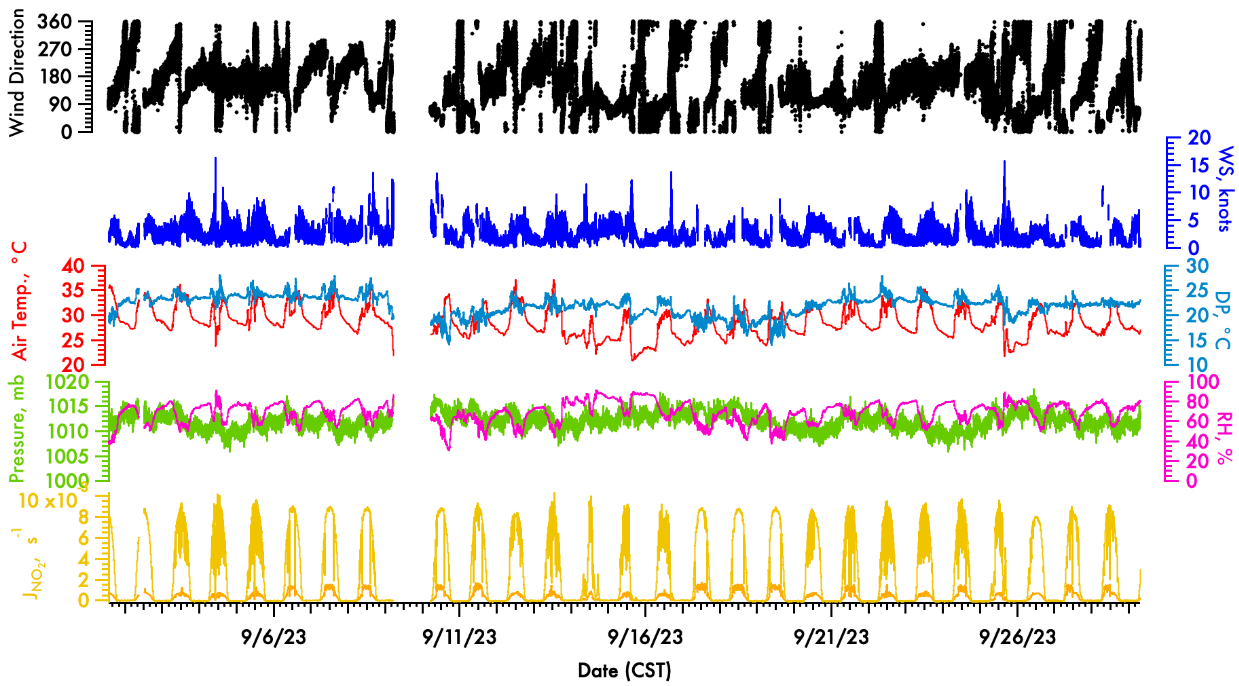


Figure 31. *Meteorological measurements collected during September 2023 on the MAQL-Sea boat sampling platform. The data gap on September 10 was due to storms knocking out power to the marina.*

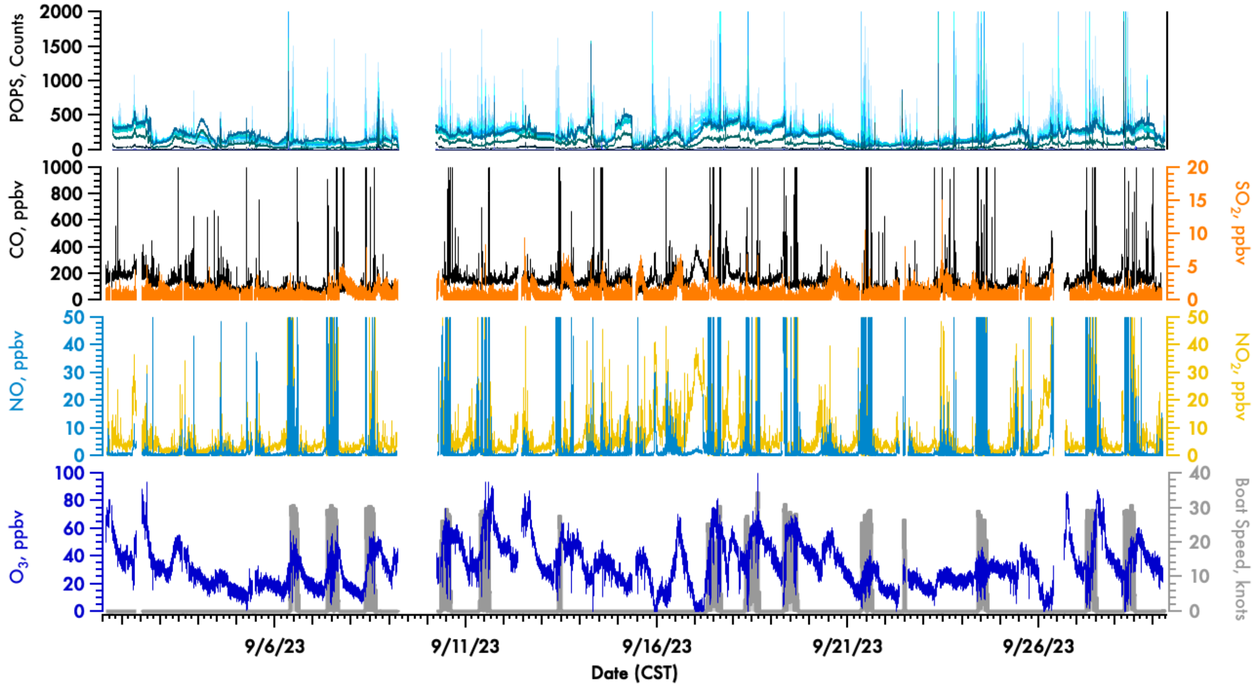


Figure 32. *Trace gas and POPS measurements collected during September 2023 on the MAQL-Sea boat sampling platform. The data gap on September 10 was due to storms knocking out power to the marina.*

Figure 31 and **Figure 32** above present an overview of the measurements collected during the campaign. One gap exists on September 9–10 which was caused by a power outage in the marina after a strong storm blew out a transformer. Once power was restored the data resumed without further extended interruptions. The boat speed is included as an indication of when the boat was underway. Additional information about selected periods is included in the following sections.

Measurement Highlight: September 18, 2023

The MAQL-Sea prepared to sample offshore on September 18, 2022 due to forecast offshore ozone. The offshore missions for this project were conducted with a local experienced captain to help familiarize the team with how to operate in the Gulf. Initially, the MAQL-Sea headed south from the dock in Seabrook through the Houston Ship Channel (HSC) to Galveston, TX to pick up the day captain and top off on fuel for the trip offshore. During the trip through Galveston Bay surface ozone was generally low to moderate (<50 ppbv), with lower ozone in southern Galveston Bay. During this portion NO_2 was widely elevated at 3–5 ppbv while encountering discreet enhanced NO_2 emission plumes from the ship traffic in the HSC (**Figure 33**).

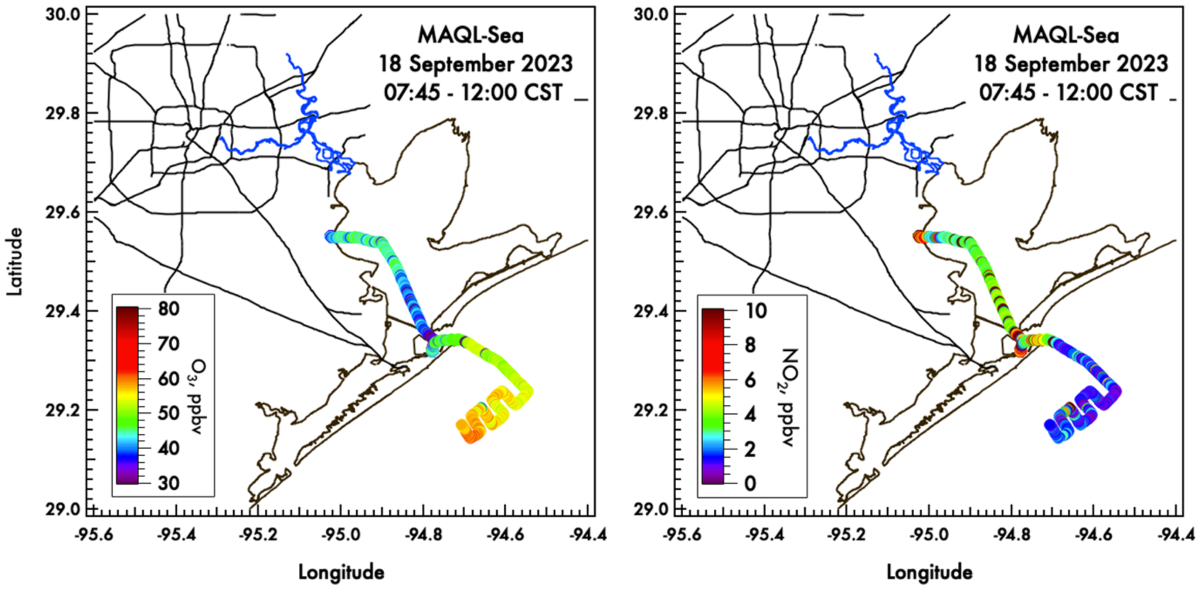


Figure 33. *Ozone and NO_2 (10s) concentrations along the path of the MAQL-Sea boat sampling platform on 18 September 2023.*

During the afternoon sampling period (12:00–16:00 CST) the MAQL-Sea measured a relatively homogeneous ozone plume over the Gulf of Mexico, approximately 60–65 ppbv. The return trip to Galveston and then Seabrook saw relatively higher values over Galveston Bay compared to offshore. Less NO_2 was seen overall in the afternoon period, but discreet plumes were observed around the Galveston and Kemah channels (**Figure 34**).

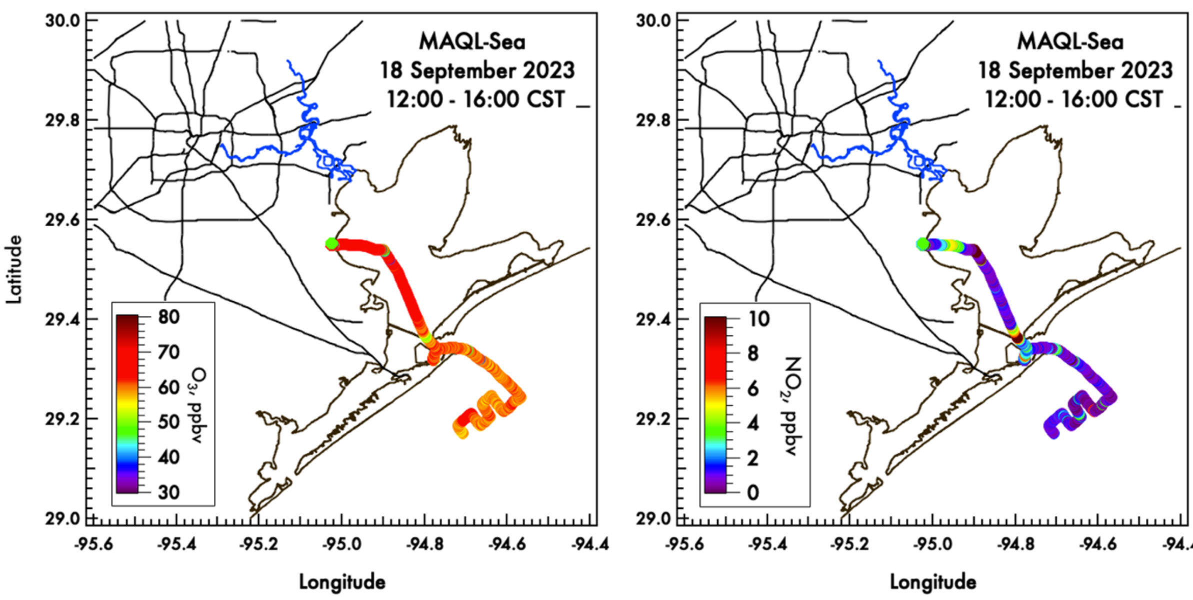


Figure 34. *Ozone and NO_2 (10s) concentrations along the path of the MAQL-Sea boat sampling platform on September 18, 2023.*

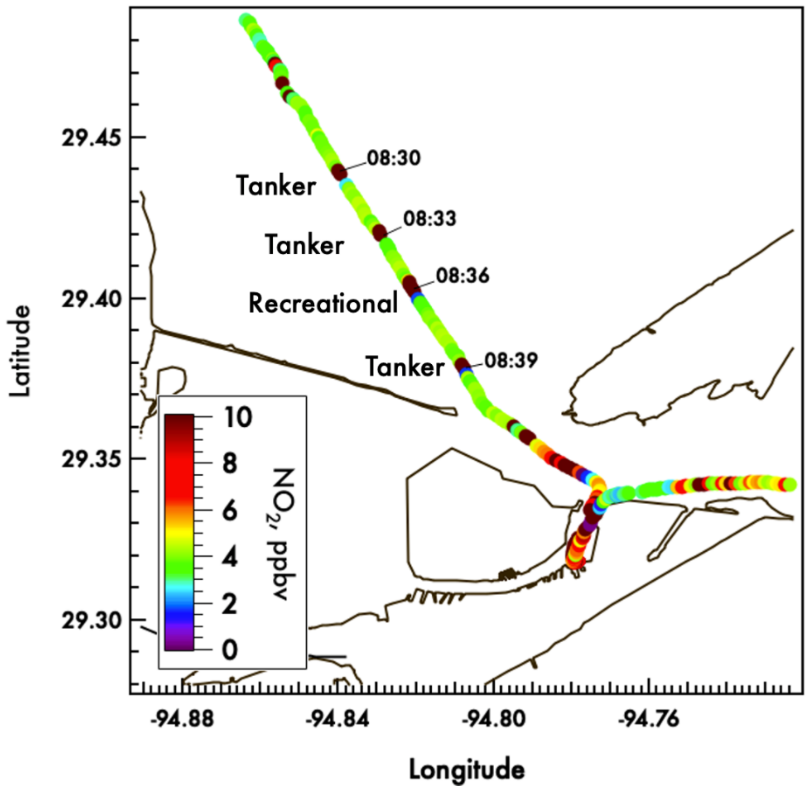


Figure 35. *NO_2 concentrations from the MAQL-Sea while encountering large commercial ship plumes in the HSC along the traverse south to the Gulf of Mexico.*

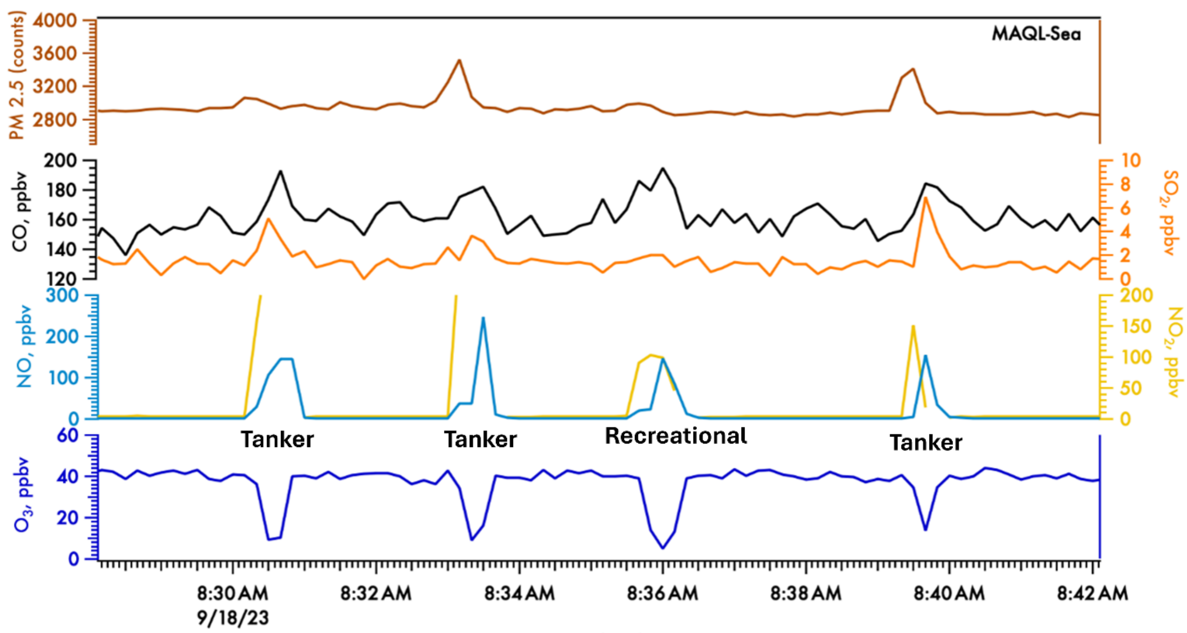


Figure 36. *Trace gas and PM $_{2.5}$ (estimate) while encountering ship emission plumes in the HSC on September 18, 2023.*

While the MAQL-Sea was traversing south from the dock in Seabrook, TX to pick up the day captain in Galveston, TX several ship exhaust plumes were encountered from passing tankers and a recreational craft close to the Galveston channel (**Figure 35**). The primary characteristic of these plumes was exceptionally high NO_x which titrated out much of the ozone for a period of 30–40 seconds on average. The tankers also observed 2–5 ppbv (10s) of increased SO_2 during the plumes with the recreational craft not observing a measurable increase in SO_2 (**Figure 36**). All the vessels did show small increases (<50 ppbv) in CO with the recreational craft showing the broadest plume, which may be related to being powered by an outboard gasoline vs. inboard diesel engine. Increases in $PM_{2.5}$ counts are noted in at least two of the three tanker plumes. These aerosols are likely soot from the diesel engines however a deeper future analysis could be performed to integrate the aerosol optical properties from the multiwavelength TAP and nephelometer to examine the associated light absorption and scattering properties to determine if the aerosols are in fact likely to be soot or potentially sulfate aerosols which could occur from processing of SO_2 from the diesel exhaust in a humid environment. It should be noted that NO and NO_2 were measured with a Thermo 42i instrument which alternates between modes. As a result, sharp transient plumes such as these can result in artifacts when there are significant gradients in the plumes on time scales shorter than the 10-second measurement cycle. In narrow plumes this can give the illusion of an apparent lead or lag in the data, such as seen in **Figure 36**. Periods where the resulting NO_2 was significantly negative due to calculation and timing issues were removed. Although this study was designed to study larger scale photochemistry on scales of kilometers to tens of kilometers, these and the numerous other commercial and recreational marine vessel emissions are noteworthy in their relative variability from one vessel to another. Future studies focused on marine vessel emissions would carry a revised payload and allow for continuous measurements of NO and NO_2 to better characterize the plumes.

As shown here, the MAQL-Sea can cover a relatively large spatial area including in the Gulf of Mexico. While sampling in the anchorage area the boat encountered areas of elevated emissions. In the Houston Ship Channel (HSC) distinct ship emission were observed while traversing south towards the Gulf of Mexico from the dock in Seabrook, TX on the western edge of Galveston Bay. September 18 also experienced widespread elevated ozone (>60 ppbv) observed by the MAQL-Sea over Galveston Bay and offshore in the Gulf of Mexico. Other trips into the Gulf demonstrated the ability to sample near oil and gas production platforms and found plumes emitting from the production activities.

3.2.3.2 VOCs

MAQL Sea VOC Data

The AROMA was operated in Labscan mode (10 min sampling intervals). **Figure 37–Figure 44** highlights the spatial and temporal VOC data collected from the AROMA on the pontoon boat.

Benzene, toluene, and isoprene data is shown in **Figure 45** for September 18 and 24, 2023. These measurements highlight the variability along the ship channel and between different days.

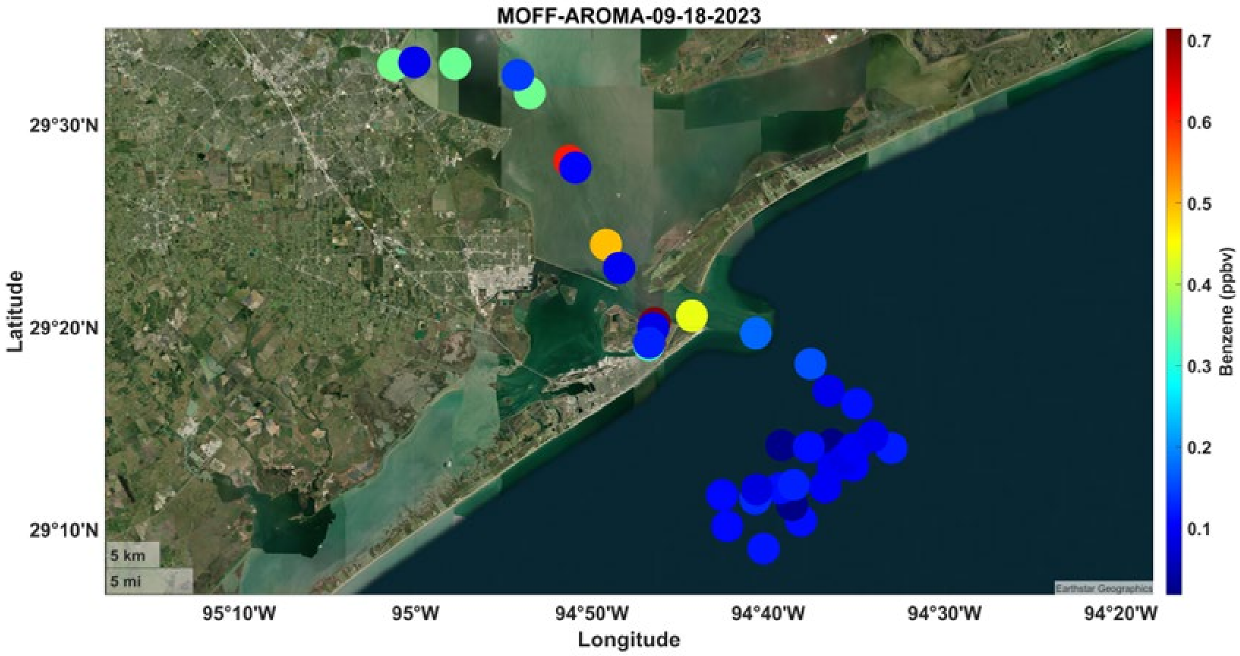


Figure 37. *Benzene measurements collected during September 18, 2023 on the MAQL-Sea boat sampling platform.*

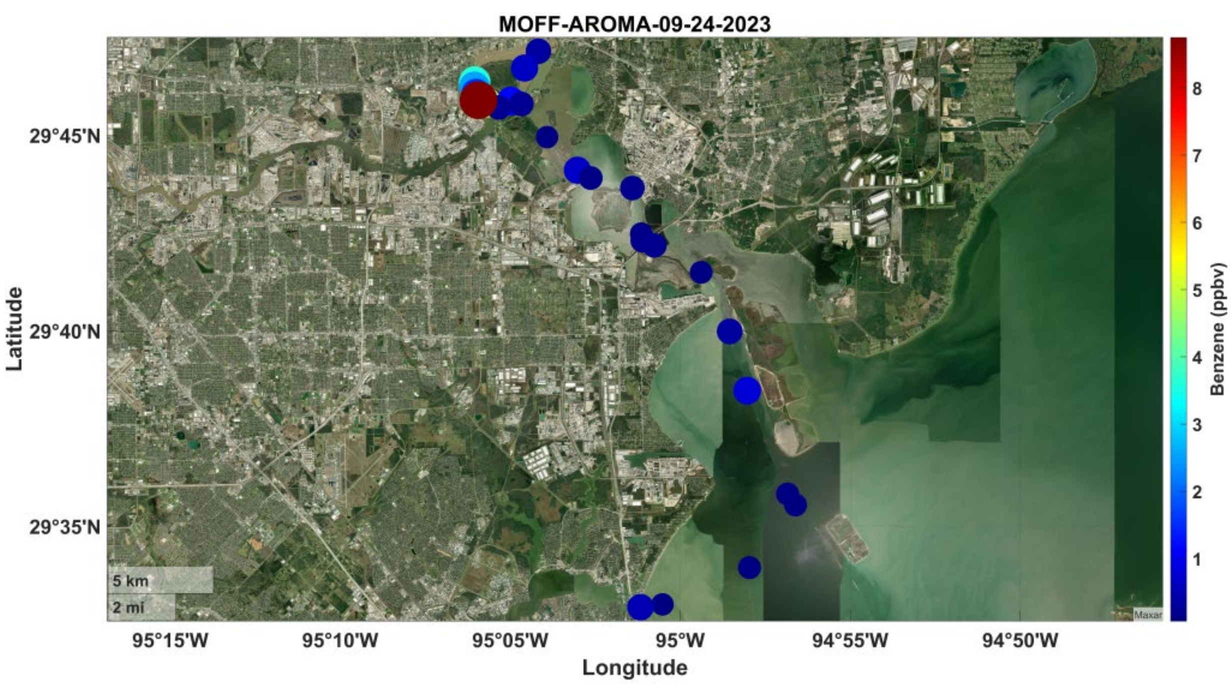


Figure 38*. Benzene measurements collected during September 24, 2023 on the MAQL-Sea boat sampling platform.*

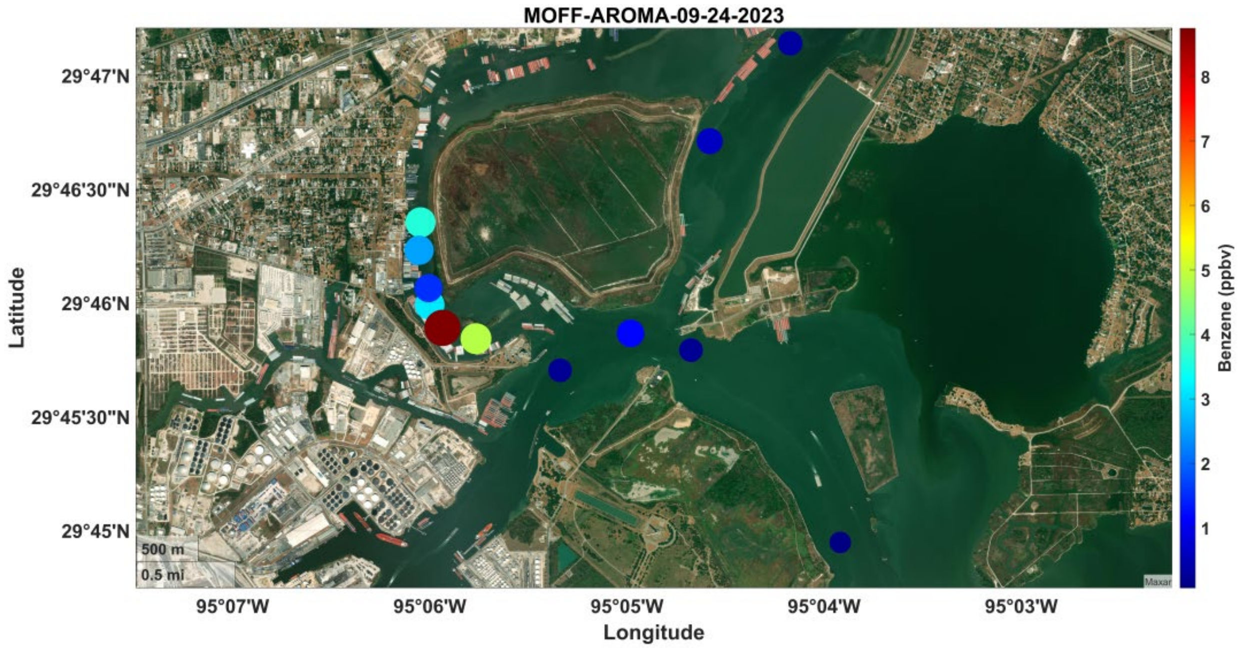


Figure 39. *Benzene measurements collected during September 24, 2023 on the MAQL-Sea boat sampling platform. This figure highlights the sampling periods near the Houston Ship Channel.*

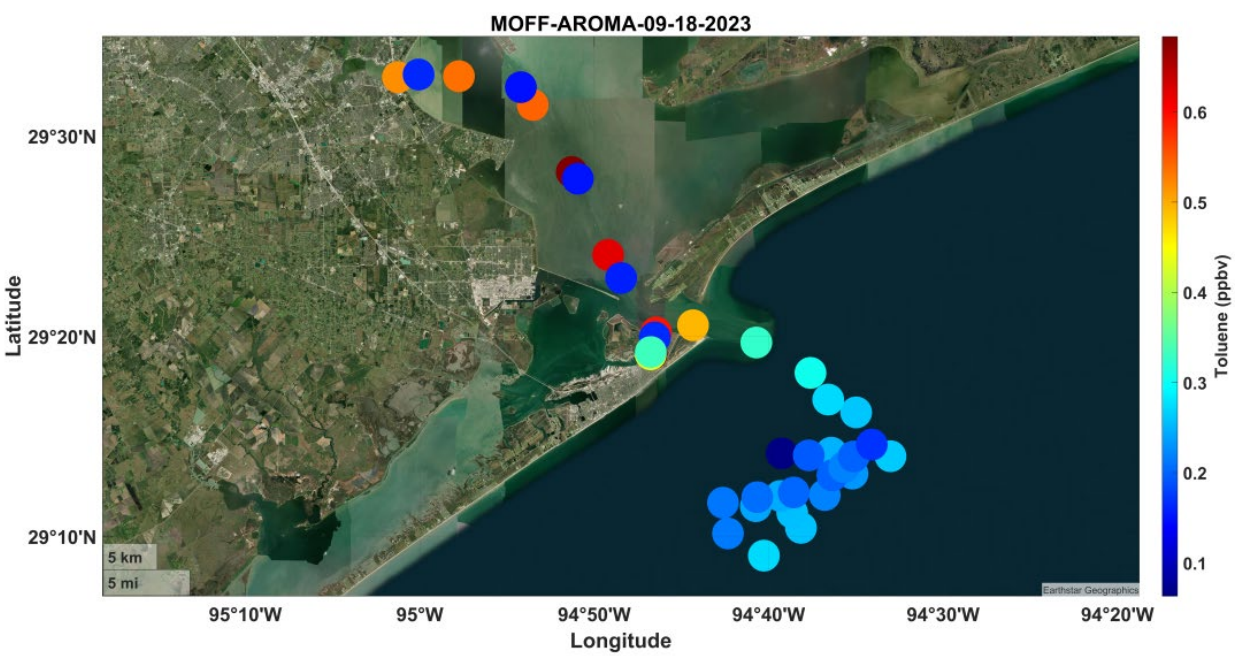


Figure 40. *Toluene measurements collected during September 18, 2023 on the MAQL-Sea boat sampling platform.*

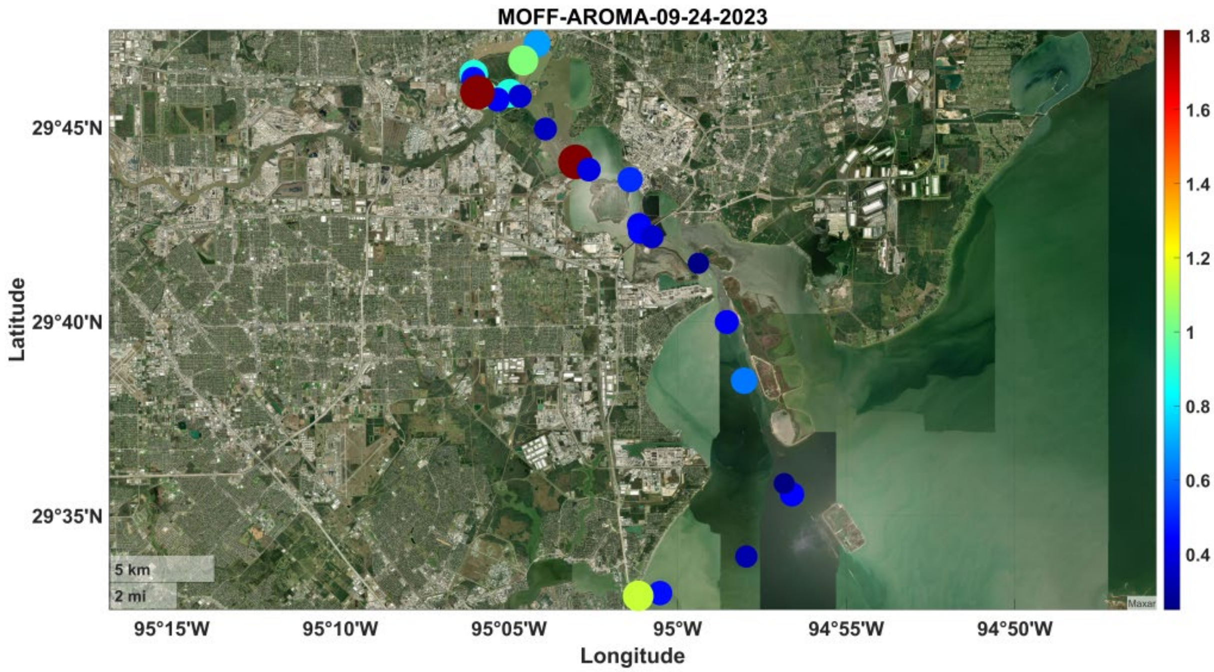


Figure 41. *Toluene measurements collected during September 24, 2023 on the MAQL-Sea boat sampling platform.*

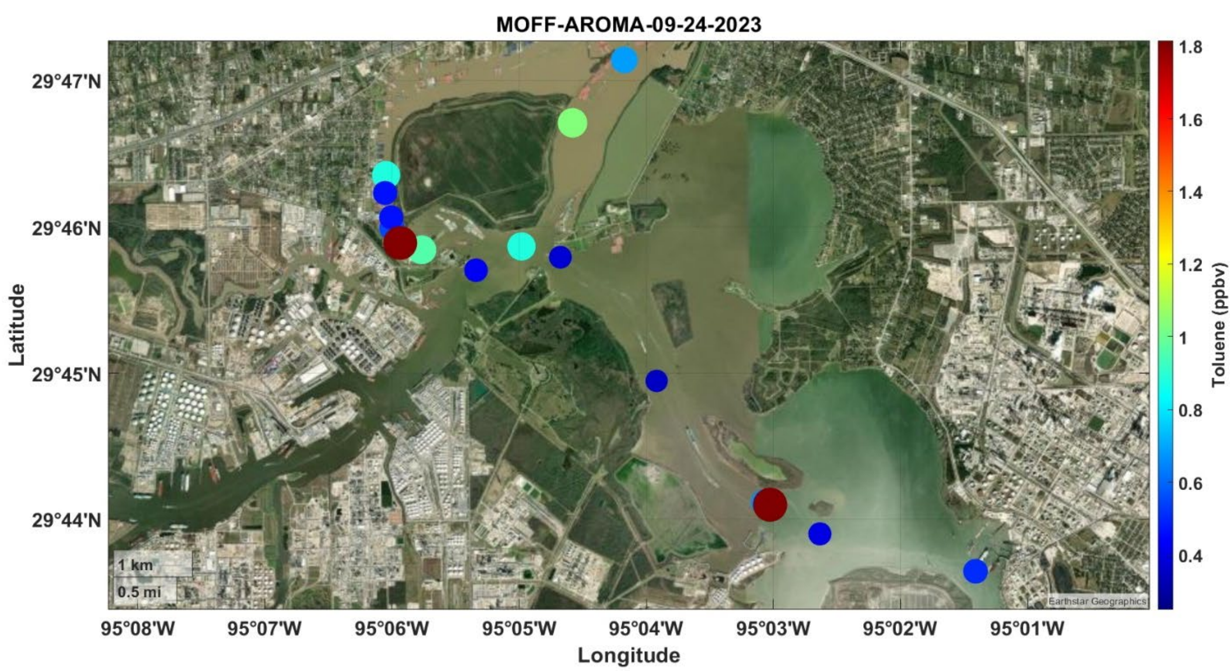


Figure 42. *Toluene measurements collected during September 24, 2023 on the MAQL-Sea boat sampling platform. This figure highlights the sampling periods near the Houston Ship Channel.*

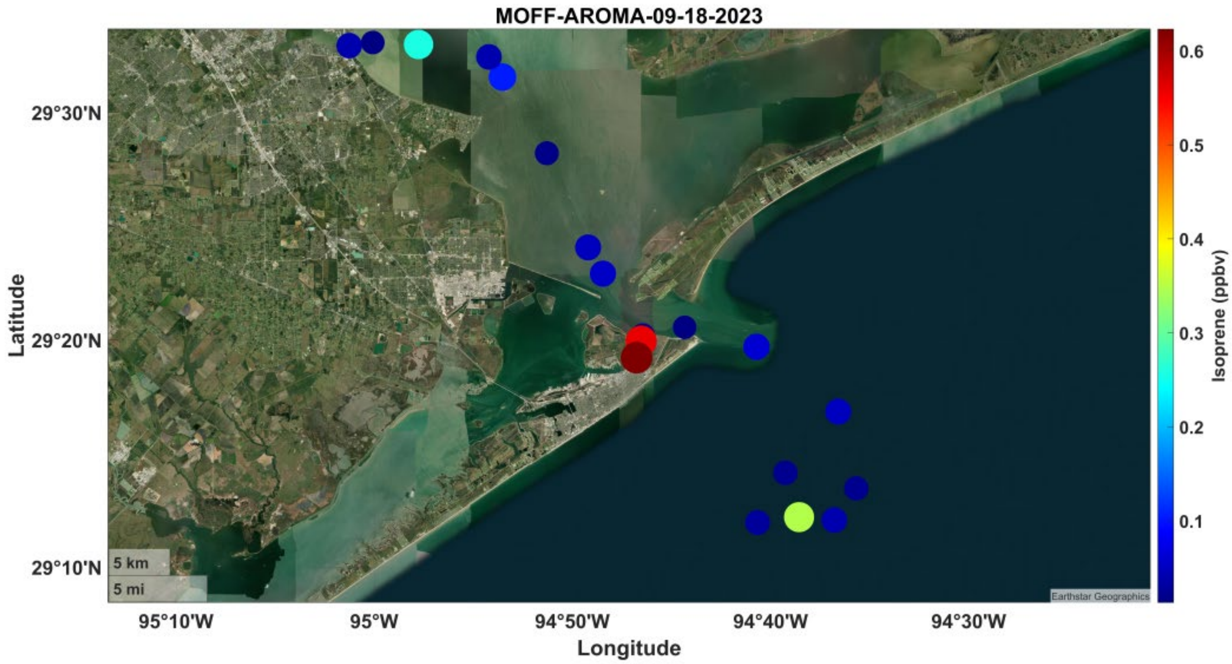


Figure 43. *Isoprene measurements collected during September 18, 2023 on the MAQL-Sea boat sampling platform.*

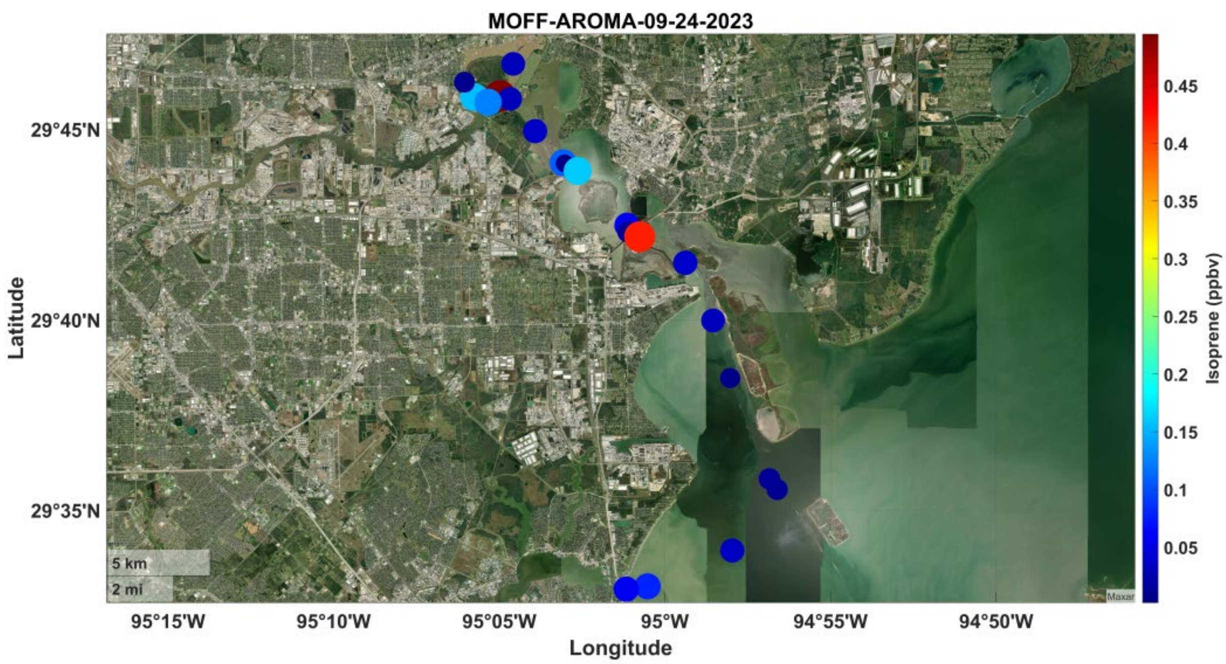


Figure 44. *Isoprene measurements collected during September 24, 2023 on the MAQL-Sea boat sampling platform.*

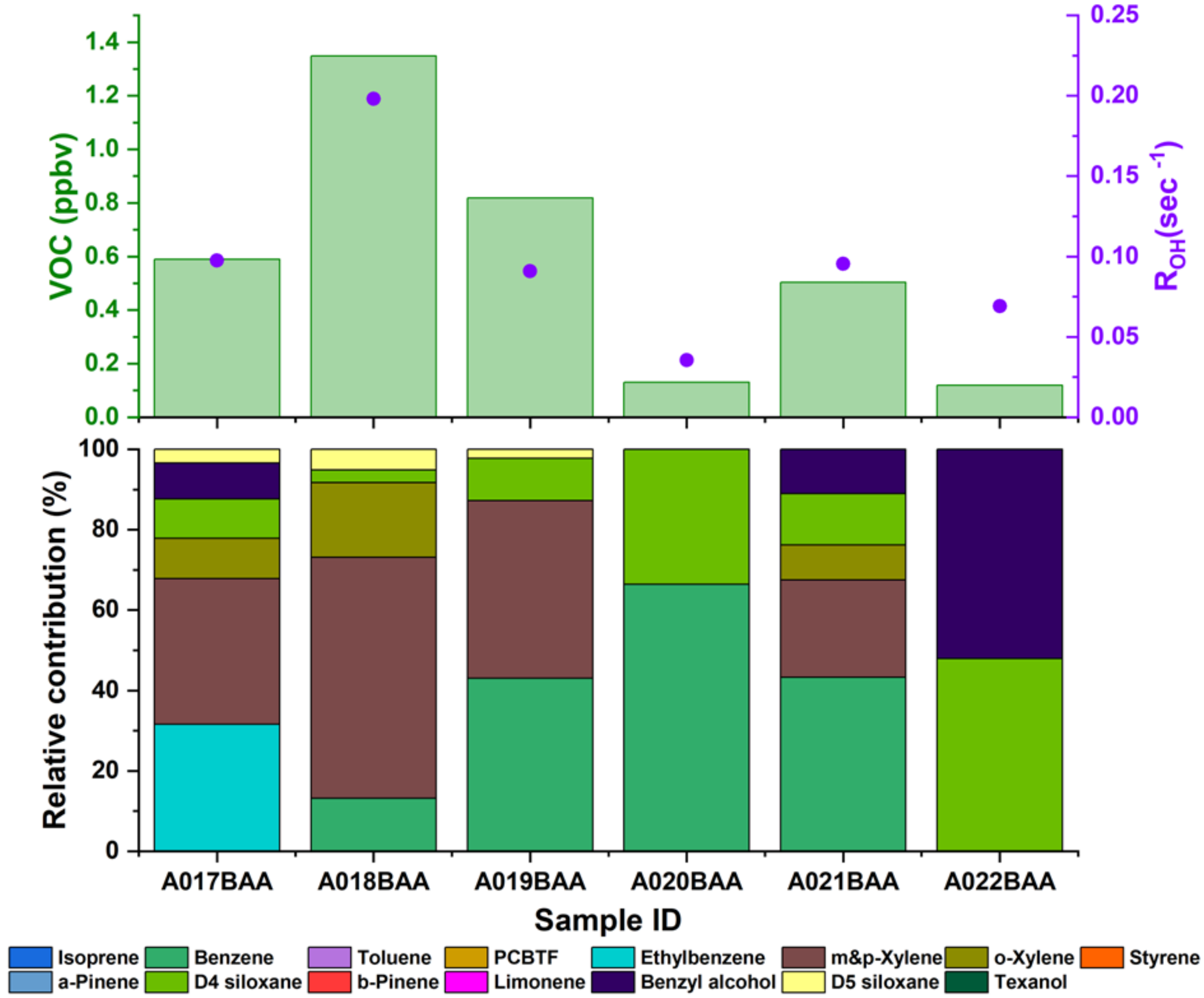


Figure 45. *VOC resin tube measurements collected during September 18 and 24, 2023 on the MAQL-Sea boat sampling platform. It is important to note, that the resin tubes provide additional chemical speciation as compared to the Labscan of the AROMA.*

Observed VOC concentrations peaked at 1.3 ppbv on 9/21 and at 0.5 ppbv on 9/24, followed by a 40% concentration reduction in the subsequent samples, see **Figure 45**. These observations are lower than TRACER-Q2 VOC measurements which had a range of 0.1–21 ppbv, with an average of 4.1 ppbv. Anthropogenic VOCs dominated the composition in all samples, particularly the xylene isomers and benzene. Contributions from ethylbenzene (maximum: 32 %), D4 siloxane (maximum: 48%), and benzyl alcohol (maximum: 52%) were also captured on both days. Note: no biogenic VOCs were identified in these samples, unlike TRACER-AQ2 samples that had between 1 and 14% contribution from isoprene. R_{OH} values varied by a factor of ~ 5 and were primarily driven by the xylene isomer concentrations. These values are similar to previous R_{OH} observations on the UH pontoon boat in late September 2022. TRACER-AQ2 observations had a range of 0.0–6.2 sec^{-1}, with an average value of 1.1 sec^{-1} due to biogenic compounds (e.g., isoprene and limonene concentrations) contributing to the OH reactivity.

3.2.3.3 Aerosols

The select aerosol data is highlighted in **Figure 46–Figure 47** and includes AAE, SAE, and eBC. The mobile absorption (three wavelengths) and scattering (three wavelengths) coefficients are not presented, however, the campaign timeseries for the aerosol absorption coefficients, scattering coefficients, AAE and SAE are shown in **Figure 48–Figure 49**.

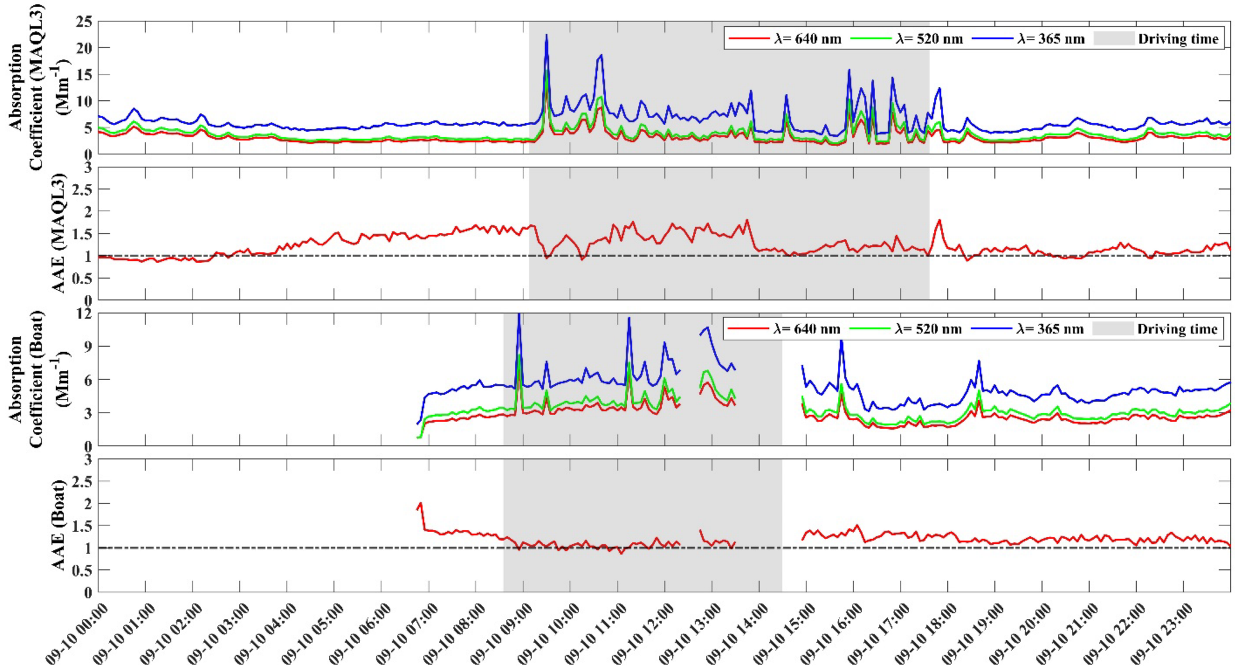


Figure 46. *MAQL-Sea campaign timeseries for aerosol absorption coefficients, scattering coefficients, AAE and SAE on September 10, 2023. Grey periods indicate mobile transects.*

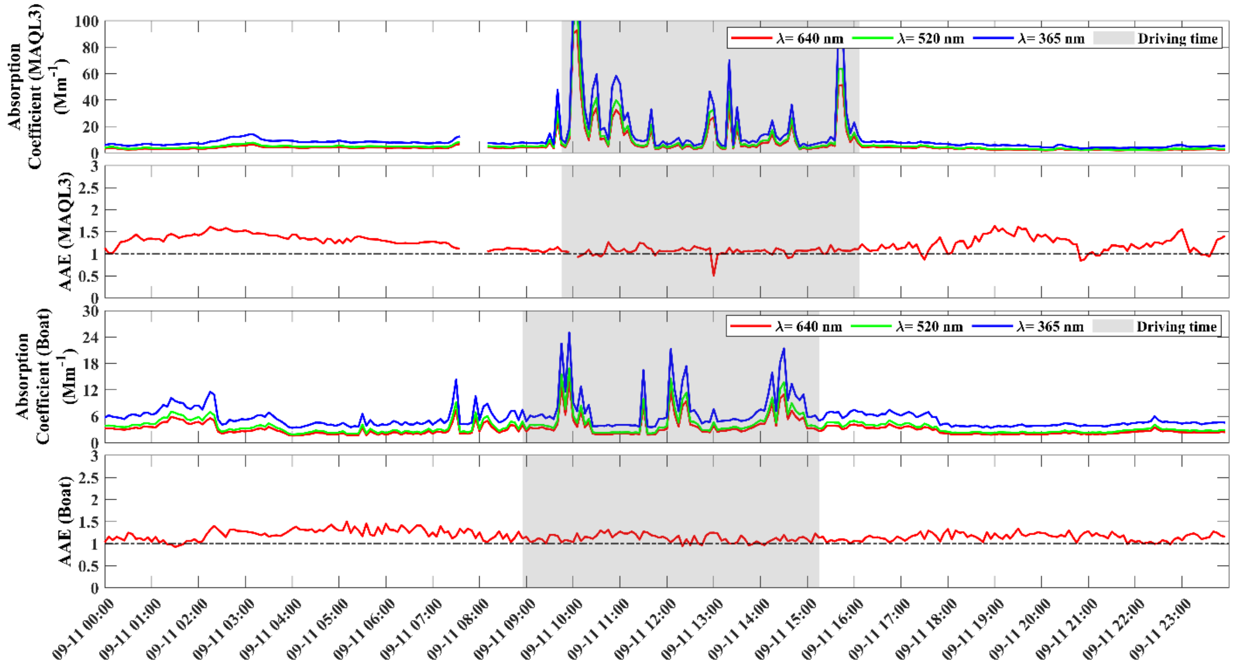


Figure 47. MAQL-Sea campaign timeseries for aerosol absorption coefficients, scattering coefficients, AAE and SAE on September 11, 2023. Grey periods indicate mobile transects.

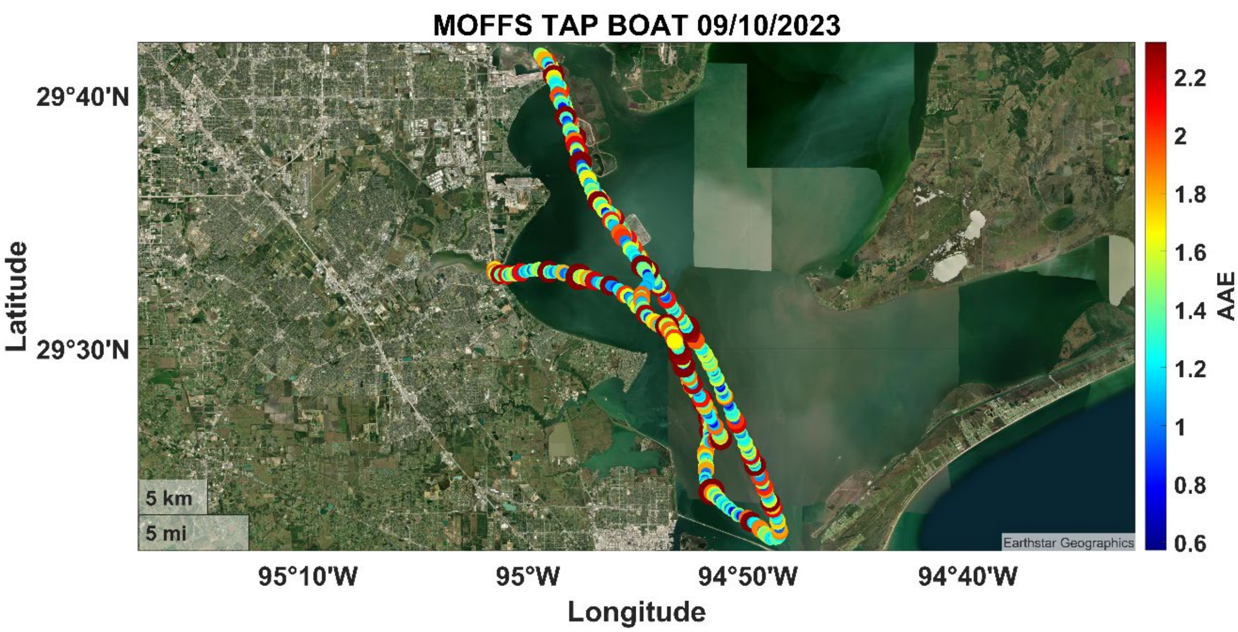


Figure 48. MAQL-Sea mobile transects of TAP AAE calculations for September 10, 2023.

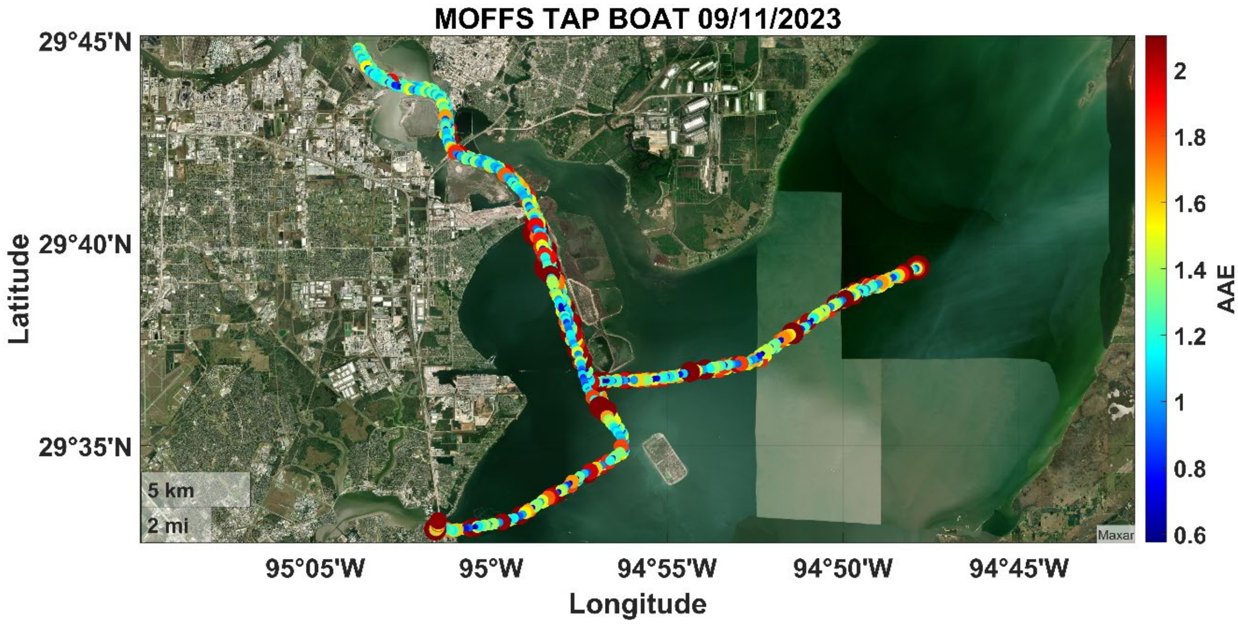


Figure 49. *MAQL-Sea mobile transects of TAP AAE calculations for September 11, 2023.*

3.3 Task 5 – Monitoring Air Quality by Use of Small Unmanned Aerial Vehicle (sUAS)

The principal goal of the small unmanned aerial system (sUAS) operations during the Mobile and Offshore Air Quality Monitoring Field Campaign in Houston was to measure vertical profiles of ozone (O_3), temperature, pressure, and humidity. The sUAS used for measurements included an Aurelia X6 Pro hexacopter, and associated ground station components. The equipment was purchased in 2021 by the University of Houston (UH) under the TCEQ funded Air Quality Data Collection Support for TRACER-AQ in Houston (TRACER-AQ) grant (PGA# 582-21-22179-015) as a platform for air quality measurements.

The primary payload for the Aurelia X6 Pro drone consisted of an aluminum sensor chassis (described thoroughly in TRACER-AQ Deliverable 10.2), two step-down DC-DC converters, a grounding busbar, and a relay board with six relays that can be controlled from the ground via the sUAS transmitter. The sensor chassis and these components are pictured attached to a perforated aluminum platform and mounted to the top of the drone in **Figure 50**. For the 2023 measurements, an EN-SCI ozonesonde was connected to an extended inlet tube was mounted to the chassis. The ozonesonde connected to an iMet-1 RSB Research Radiosonde which could transmit the ozone data as well as the temperature, pressure, and humidity measurements from the radiosonde's probe. These components made up the standard payload, but the sUAS was also capable of carrying other instruments as in **Figure 51**, where the sUAS is shown with a Baylor University VOC payload mounted to the bottom.

Figure 50. *The Aurelia X6 Pro with the sensor chassis, electrical system components, and the upper platform mounted to the top of the drone.*

Figure 51. *The Aurelia X6 Pro flying at San Jacinto Battleground Park in 2022. The primary payload is mounted on top, and a Baylor University VOC payload is mounted on the bottom.*

The use of ozonesondes to collect data on the sUAS was motivated by the low weight (~240 grams) and relatively low cost of the instruments. Furthermore, the team had extensive experience using them on weather balloons. In 2022, an sUAS ozonesonde payload was flown several times under the TRACER-AQ2 grant (PGA #582-22-32022-021) next to the UH Launch Trailer, and near Moody Tower, aiming to demonstrate that the sUAS ozonesonde data were in reasonable agreement with other nearby measurements. The intercomparison analysis was performed during the TRACER-AQ Analysis project (PGA #582-23-42586-027) and the measurements compared well.

Preparations for the 2023 Mobile and Offshore Air Quality Monitoring Field Campaign included inspection and/or replacement of payload and sUAS components, test flights, and review of updated FAA regulations for sUAS operations. During the inspection of sUAS components the Remote Pilot In Command (RPIC) discovered that 4 out of 5 sets of the 21,000 mAh 22.2 VDC batteries for the sUAS were severely expanded and therefore not safe for use. New batteries were ordered, but not delivered until well into the campaign. However, the sUAS was also equipped to be powered by an Elistair SAFE-T power tether station. Using the 80 m power tether and a small backup battery, the sUAS was restricted in altitude by the length of the cable, but it could remain in the air for many hours at a time. The tether station required a 30-Amp electrical connection to either a generator or RV-style shore power hookup. Shore power is available at the UH Coastal Center flight location. For other locations, a generator could be used (see **Figure 52**). The power tether allowed the RPIC to continue multi-hour sUAS operations until the new batteries arrived.

Figure 52. *sUAS with the standard ozone payload flying in the "breathing zone" of 2-3 meters at the UH Technology Bridge while powered by the SAFE-T power tether. The tether station is powered by a generator in the back of the pick-up truck.*

Review of the updated FAA regulations revealed new capabilities for flying at night, but also a need to purchase a remote ID module for the sUAS so that it could meet new requirements. A remote ID module was ordered, but due to vendor and shipping delays, it was not delivered until after the campaign. The updated rule requiring identification information to be transmitted by all drones operating under Part 107 was originally set to effect on September 16, 2023. In September however, the FAA announced that the new rule would be delayed for six months to allow more time for pilots to update their systems.

3.3.1 Quality Control / Quality Assurance for sUAS Flights

At least two ozonesondes were prepared for each sUAS flight, a primary and a backup sonde. The initial preparation of drone sondes was performed according to the same procedures as balloon ozonesondes (described further in section3.4.1). The ozonesonde electrochemical concentration cell (ECC) cathode and anode solutions were prepared and provided by Dr. Paul Walter (St. Edwards University). Once prepared, the drone sonde was attached directly to the payload chassis rather than packed into an ozonesonde box. A strip of insulating tape was added to the bottom of the cells to prevent the cell wires from shorting to the aluminum chassis.

After each flight, drone ozonesondes could be refreshed with new ECC solutions and used again after another background ECC current test was conducted to establish the baseline and confirm the sonde's most basic functions. For ozonesondes that were used regularly, more thorough preparations that included O_3 response and pump flowrate tests were repeated every few flights to ensure the ozonesonde was still operating normally. These preparation procedures matched a typical day-of-flight preparation for a balloon launch. See the website (https://www.patrickcullis.com/ozonesonde-instructions.html) maintained by Patrick Cullis (NOAA) for further explanation of preparation procedures.

If any drone sonde failed to perform according to generally accepted standards, the sonde was repaired if possible and the tests were performed again. If problems were not resolved, a different ozonesonde was used.

During sUAS flights throughout the campaign, careful attention was paid to the live data transmitting via the iMet so that any problems could be addressed immediately. Some issues that could prevent useful data from being received were signal interference, shorted ozonesonde cells, lack of power to the ozonesonde, overheating of the ozonesonde pump, or depletion of the ozonesonde solutions (for very long flights). With careful monitoring of the data, these issues could typically be addressed in the field with only a minor interruption in data collection. Thorough notetaking and adherence to established checklists and procedures also helped to ensure data quality and reliability.

Ascent speeds were typically lower than descent speeds during flights. The reason for this difference was that the UH sUAS data has shown that if a vertical ozone gradient exists (with a positive relationship between ozone and altitude) then measurements of O_3 are higher on descents than ascents. This is likely because during descent, the drone flies through a column of its own disturbed air which creates a very turbulent region around the drone and some of the air is recirculated by the rotors. Researchers at University of Utah and Weber State University also observed this phenomenon (Saad & Sohl, 2021). Based on experimental observations as well as their computational fluid dynamics (CFD) calculations, they also hypothesized that O_3 rich air is pulled from higher altitudes and persists through descents due to recirculation. Their CFD simulation and experimental results supported this conclusion. On ascents, samples are pulled from above the drone where the air is largely unaffected by the rotors. Therefore, only ascent profiles are typically used for numerical analysis of UH sUAS data, and descent speeds were increased to conserve battery, allow for additional ascent profiles, and minimize gaps in representative data.

Python script was used for the initial processing of the data from the ozonesondes and radiosonde. The script first eliminated extreme values that resulted from missing data points and sensor errors. GPS altitudes, latitudes, and longitudes that were outside of a reasonable range for the location were also flagged as erroneous data. Then, as plots were generated, the altitude above ground level was calculated by finding the lowest GPS altitude measured by the iMet radiosonde not flagged as missing data and used the minimum as the ground level.

3.3.2 Results for Measurements

During the Mobile and Offshore Air Quality Monitoring field campaign, the sUAS was used on five flight days. It was flown at the University of Houston Technology Bridge (formerly known as ERP) on September 8. It was flown at the University of Houston Coastal Center on September 10, 11, 13, and 17. Appendix C contains figures and summarized field notes for each flight day. **Table** 5 shows the maximum ozone measured by the sUAS within each hour it was active during the campaign. The maximum values were found by first averaging the 1 s ozone data to 30 s, then finding the maximum 30 s value within each hour.

***Table** 5. Maximum 30 s averaged ozone measured by the sUAS each hour, and location of each flight.*

Date	6:00 a.m.	7:00 a.m.	8:00 a.m.	9:00 a.m.	10:00 a.m.	11:00 a.m.	12:00 p.m.	1:00 p.m.	2:00 p.m.	Location
9/8					58	68				UH Tech Bridge
9/10	38	44								UH Coastal Center
9/11					77	80	88	93	98	UH Coastal Center
9/13	48	48	50							UH Coastal Center
9/17	43									UH Coastal Center

Since the first four flights were conducted using the power tether, the maximum altitude for these flights was under 80 m due to the length of the tether. The September 8 flight at UH Technology bridge was even lower (61 m) due to airspace restrictions. The September 17 flight reached the full 121 m (400 ft) height allowed by Part 107 FAA regulations.

Three of the flights took place in the early morning with the goal of capturing vertical profiles during the transition from a stable nocturnal to convective boundary layer. **Figure 53** shows the sUAS altitude, temperature, and relative humidity data for the September 13 flight and vertical gradients are evident throughout the morning. Notably, in the early morning, temperature increases and humidity decreases with increasing altitude. Between approximately 7:15 a.m. and 7:30 a.m. however, that pattern reverses. Thereafter, temperature decreases with increasing altitude and humidity increases with greater altitude. The timing of this change also corresponds to the transition from a strong vertical O_3 gradient to uniform O_3 profiles. **Figure 54** shows the September 13 O_3 profiles, including those that occurred after the gradient had dissipated.

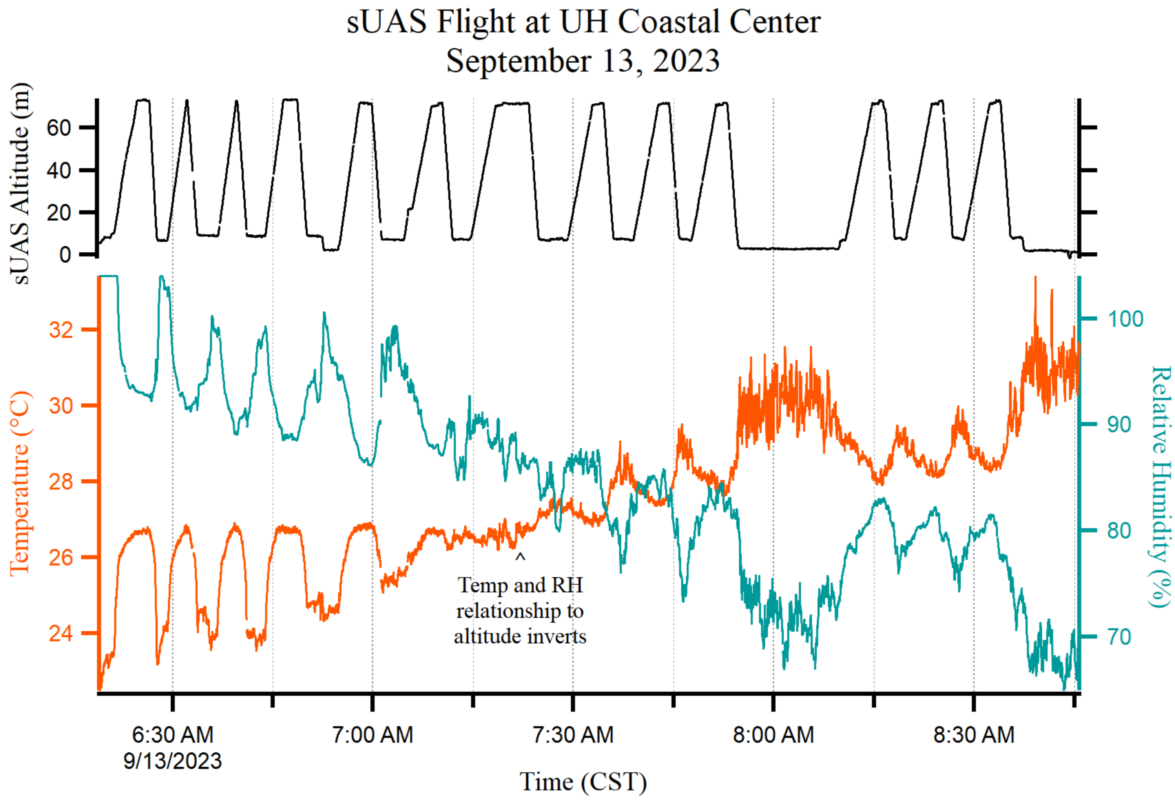


Figure 53. *Altitude (top axis), temperature (bottom left axis), and humidity (bottom right axis) versus time during the UH Coastal Center sUAS flight on September 13, 2023. Between 7:15 and 7:30 a.m. the temperature vs. altitude and humidity vs. altitude relationships reverse.*

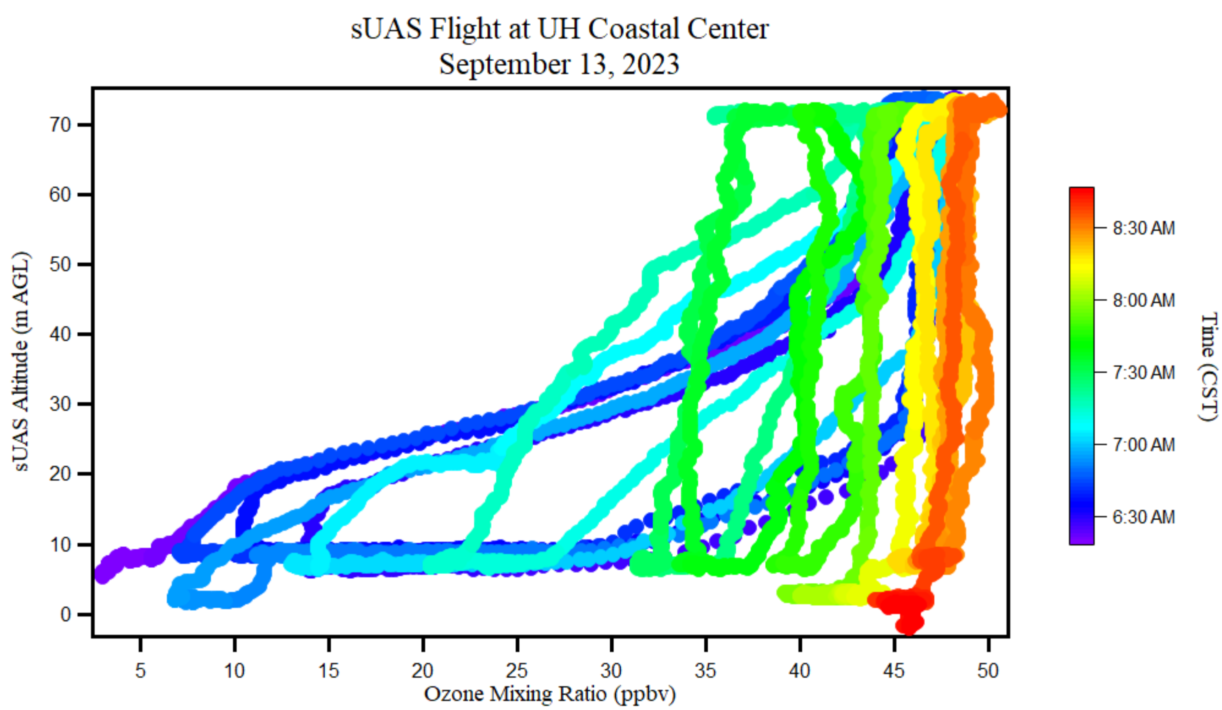


Figure 54. *All sUAS altitude vs ozone profiles, colored by time (CST) measured at UH Coastal Center on September 13, 2023. Official sunrise occurred at 6:05 a.m. CST.*

The RPIC began the sixth sUAS profile for September 13 at 7:04 a.m. and the gradient ranged across 40 ppbv between roughly 5 and 70 m. The seventh profile (starting at 7:14 a.m.) spanned only 25 ppbv, and by the eighth profile (starting at 7:20 a.m.) the range had reduced to only a 9 ppbv difference between the bottom and the top of the profile, marking a significant change in the low altitude atmosphere.

Drone measurements of vertical O_3 gradients provide important data for understanding ozone surface titration, deposition and photochemical production, but some profiles can also capture multiple air layers and point to O_3 entrainment. September 13 (**Figure 55**) and September 17 (**Figure 56**) profiles both revealed inflection points within the drone range. Inflection points can mark interfaces between tropospheric air masses as ozone can vary dramatically due to the dynamics and differing chemical compositions between layers (Peletin et al., 2018 and Selkirk et al., 2010). Deeper analysis of the gradients observed on these two days could include inspection of inflection point heights and possible O_3 entrainment from residual air masses.

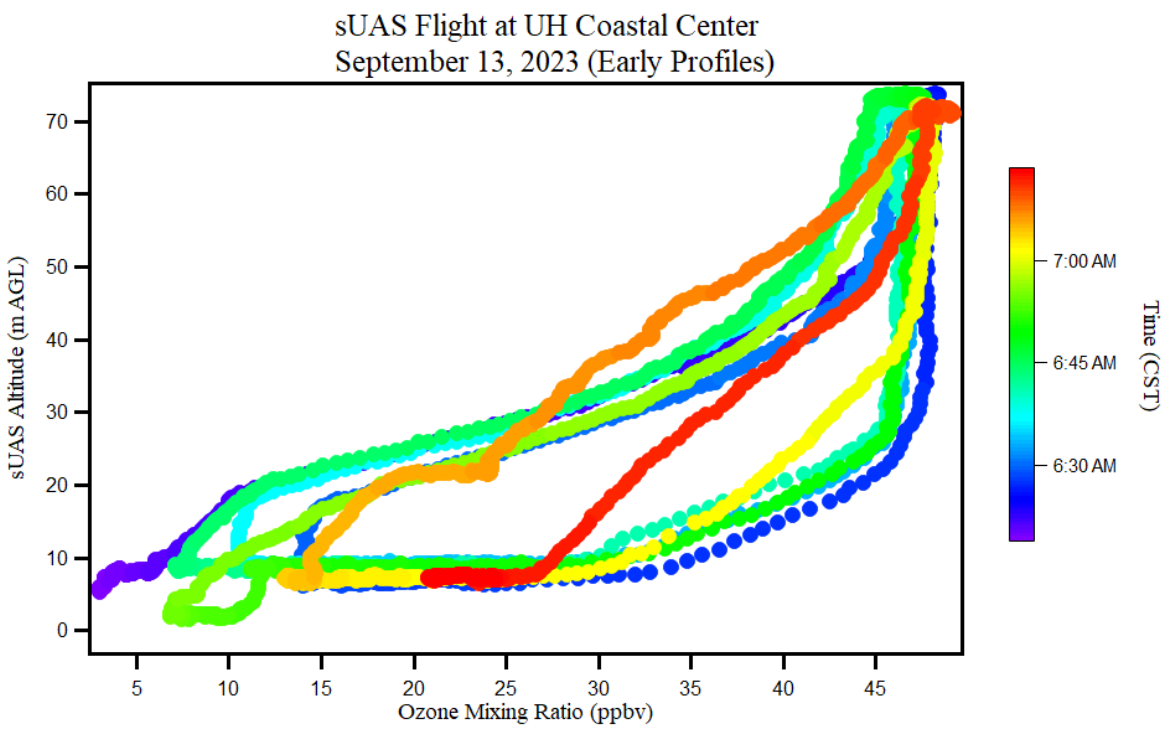


***Figure 55**. sUAS altitude vs ozone profiles, colored by time (CST) measured at UH Coastal Center on September 13, 2023. Only the first several profiles are shown to more clearly demonstrate that there is an inflection point in the profiles. Official sunrise occurred at 6:05 a.m. CST.*

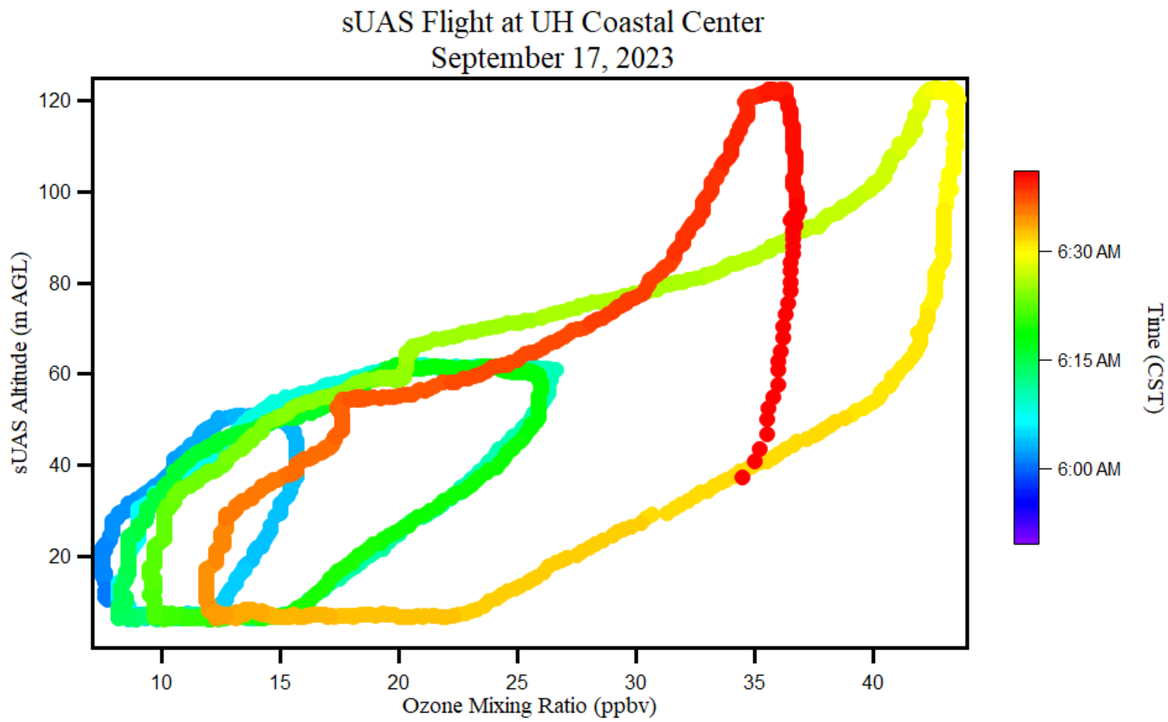


Figure 56*. sUAS altitude vs ozone profiles, colored by time (CST) measured at UH Coastal Center on September 17, 2023. Official sunrise occurred at 6:07 a.m. CST.*

The sUAS platform encountered three major problems during 2023 measurements. The first was a "radio failsafe" error that prevented a test flight on August 28. The error appeared immediately after the drone propellers were armed (started). They disarmed promptly and the radio failsafe message could not be cleared. After troubleshooting with the sUAS vendor it was found that the transmitter (controller) for the drone needed to be factory reset, which prompted a need for a product key. The vendor could not supply a key until September 6 so no sUAS measurements could be contributed until the first flight on September 8.

The second problem did not prevent sUAS measurements from continuing, but it did require more manual adjustments by the RPIC during flights as the drone LiDAR altimeter was giving inaccurate values. On September 11, over the course of 2.5 hours of continuous flight on the tether, the altitude gradually became more inaccurate. By the end of flight, the drone was reporting that it was at an altitude of 19 m above ground level while it was landed on the ground. On September 12, the outermost glass on the LiDAR laser and receiver were cleaned with a cotton swab and 90% alcohol. This solution appeared effective, and the altimeter performed normally during the entire September 13 flight.

The greatest setback for the sUAS occurred on September 17, 2023. A new set of batteries was used for the first time. After approximately 40 minutes of data collection, the batteries ran low. As the pilot was attempting to land, the voltage dropped off faster than expected based on experience with the prior battery sets and the drone lost thrust. It descended uncontrolled into the prairie and was damaged in several places. Due to the damage to the arms and battery compartment, the drone was unable to be flown again for the remainder of the campaign.

The RPIC worked with the sUAS vendor to develop a plan to rebuild the drone and make some improvements to enhance drone performance and resilience for future campaigns. Due to the design of the original Aurelia X6 Pro, a chip in a connection point for one of the arms necessitated the replacement of the entire drone body because it is all one piece. This frame will be replaced with an Aurelia X6 MAX frame, which is an upgraded, more modular design. All six arms of the drone will also be replaced with compatible X6 MAX arms. Another improvement will be in the LiDAR altimeter. Newer versions of the Aurelia drones use a Garmin altimeter system which is reportedly more reliable than previous altimeters, so the altimeter that was damaged in the accident will be upgraded to this new version. As the sUAS was insured, the UH insurance policy has paid for the cost of the rebuild and as of the writing of this report, the necessary parts have been ordered from UAV Systems International, and efforts to rebuild and improve the sUAS platform will begin as soon as the necessary resources are available.

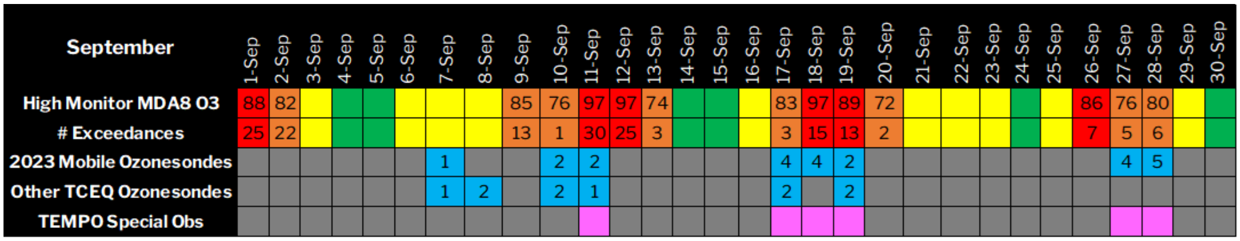
With the improved drone and revised low voltage procedures, the sUAS has great potential for future operations exploring convective boundary layer development and O_3 entrainment. Very early morning flights beginning before sunrise and continuing through development of the mixing layer would offer great opportunities to sample through multiple air layers and observe changes that occur throughout the morning. Taking advantage of Part 107 regulations that allow for higher altitude flying near towers would increase the likelihood of boundaries falling within the drone range. The UH Coastal Center has a tower approximately 42 tamum tall that would effectively increase the maximum flight altitude to 163 m if the drone is flown close to the tower. Evening flights may also be useful as they would present an opportunity to observe boundary layer collapse and the progression to more stable layers at night.

Furthermore, additional instrumentation could increase the platform's potential for air quality and meteorological studies. The addition of SO_2 and NO_2 sondes on the sUAS would help to more precisely determine the role these compounds play in the reduction of observed O_3 seen during morning, evening, and daytime flights. A small, portable, ground-based weather monitoring system could also be useful for analysis as it would provide highly localized meteorological information relevant to changes in O_3, temperature, and humidity profiles. It would also serve as a verification tool for the iMet radiosonde carried by the drone to ensure accurate met data is being collected.

3.4 Task 6 – Ozonesonde Launches

For the 2023 Mobile Measurements campaign, there were 24 ozonesonde launches in September 2023 (shown as "2023 Mobile Ozonesondes" in **Figure 57**). From the TCEQ Ozonesonde Launches in 2023 project (PGA #582-23-41323-026) there were 10 additional ozonesonde launches from the HGB region in September (shown as "Other TCEQ Ozonesondes" in **Figure**

57). Profiles of the first 10 km of the ascent of the 24 ozonesondes are shown in the appendices in **Figure 151** and **Figure 152**.



September	1-Sep	2-Sep	3-Sep	4-Sep	5-Sep	6-Sep	7-Sep	8-Sep	9-Sep	10-Sep	11-Sep	12-Sep	13-Sep	14-Sep	15-Sep
High Monitor MDA8 O3	88	82							85	76	97	97	74		
# Exceedances	25	22							13	1	30	25	3		
2023 Mobile Ozonesondes							1			2	2				
Other TCEQ Ozonesondes							1	2		2	1				
TEMPO Special Obs															

September	16-Sep	17-Sep	18-Sep	19-Sep	20-Sep	21-Sep	22-Sep	23-Sep	24-Sep	25-Sep	26-Sep	27-Sep	28-Sep	29-Sep	30-Sep
High Monitor MDA8 O3		83	97	89	72						86	76	80		
# Exceedances		3	15	13	2						7	5	6		
2023 Mobile Ozonesondes		4	4	2								4	5		
Other TCEQ Ozonesondes		2		2											
TEMPO Special Obs															

Figure 57. *Listing of the number of ozonesonde launches on a given day in September 2023. The color of the cells in the first two rows refers to the AQI index and shows the highest value MDA8 [O3] (first row) and the number of ozone exceedances out of the 42 monitors in the HGB CAMS network. The cells in magenta show the days that had two-hour windows with special high-frequency (~10 minute) TEMPO observations.*

3.4.1 Quality Control / Quality Assurance for Ozonesonde Launches

Ozone profiles for this project were measured using the electrochemical concentration cell (ECC) type ozonesonde instrument (Komhyr 1972; Komhyr 1986). All ozonesondes use 0.5% KI solution recommended by the Jülich Ozone Sonde Intercomparison Experiment (JOSIE), which found biases <5%, a precision of 3–5%, and an accuracy of 5–10% below 30 km (Smit et al. 2007; Thompson et al. 2019). Patrick Cullis (NOAA) maintains a website (https://www.patrickcullis.com/ozonesonde-instructions.html) that describes the ozonesonde conditioning and calibration procedures.

The campaign employed the InterMet iMet-4RSB radiosonde, which collects pressure, temperature, humidity, GPS location, and GPS-derived wind speed and direction. The radiosondes are connected to the ozonesondes and transmit data (~one data packet per second) that can be received by an antenna at the surface.

Our default balloon size is the 600-gram balloons that carry our payloads to 27–30 km before bursting. We used 350-gram balloons that carried our payloads to altitudes of 22–24 km before bursting in instances when a lower burst altitude had a more favorable expected landing site based on the balloon trajectory.

Ozonesonde data is processed by Skysonde software. The data is then converted to the ICARTT format, which consists of a text file with a header followed by columns of data in comma separated values (CSV) format, found on the Hoth data archive (https://hoth.geosc.uh.edu:5001/sharing/BUy4wXng0). The data is also hosted on the NASA STAQS data archive (https://www-air.larc.nasa.gov/missions/staqs/), which will become publicly available in April 2024.

3.4.2 Results for Measurements

On six days there with two-hour windows with special high frequency (~10 minutes) TEMPO observations: September 11 (12–2 pm CST), September 17 (12–2 pm CST), September 18 (12–2 pm CST), September 19 (12–2 pm CST), September 27 (8–10 am CST), and September 18 (8–10 am CST). Most of the ozonesondes were launched on those days with high intensity during the high-frequency TEMPO observations.

September 11 was in post-frontal conditions (**Figure 58**). Thirty of the 42 CAMS in the HGB region exceeded the ozone standard, and the C53 Bayland Park monitor had the highest MDA [O3] of 97 ppbv. The 24-hour wind run for the C53 Bayland Park monitor (**Figure 58**) shows that surface winds were out of the NE in the early morning and that ozone was highest when winds were slow and out of the east in the afternoon.

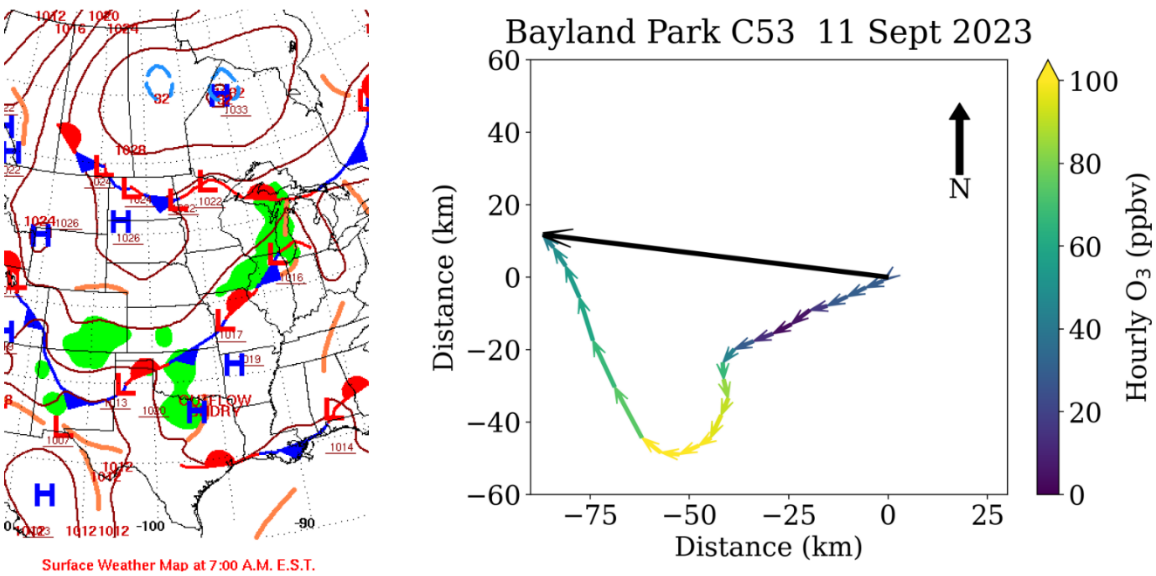


__Figure 58.__ Left: Weather map for September 11, 2023. Right: 24-hour wind run for the C53 Bayland Park monitor on September 11, 2023, where the hourly wind vectors are colored by the ozone mixing ratio.

Figure 59 shows the launch locations and first 3 km of the ozone profiles for each of the ozonesondes launched on September 11. The early morning sonde from the University of Houston shows a shallow surface layer (~300 m) where ozone was titrated away and ~55 ppbv of ozone aloft in the residual layer. Two ozonesondes were launched from the MAQL-Sea in Galveston Bay.

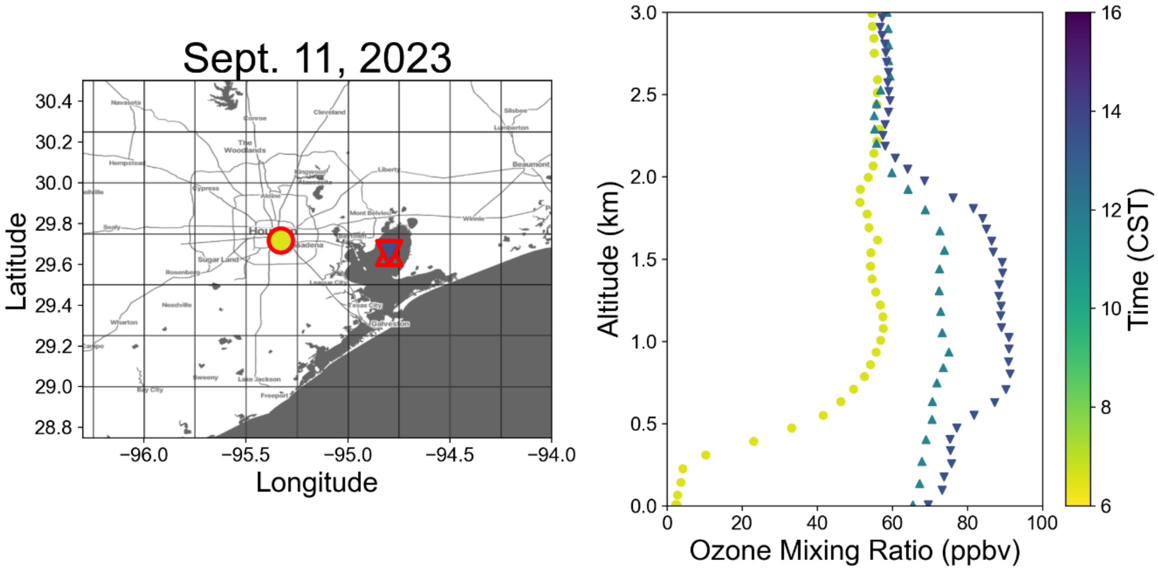


Figure 59. *Left: Ozonesonde launch locations on September 11, 2023. Right: Ozonesonde profiles for the first 3 km, colored by time of day. Launch locations are distinguished by shape.*

The afternoon ozonesonde from Galveston Bay has an ozone enhancement above the marine layer. Winds are out of the south and ozone is ~70 ppbv in the marine layer, which extends from the surface up to approximately 0.5 km (**Figure 60**). Winds shift to out of the NE above the marine layer up to approximately 1.8 km (the top of the boundary layer), and ozone is ~90 ppbv. This is a potential indication of air mass aloft being influenced by the Beaumont area. It is an open question on how well TEMPO retrievals will be able to measure ozone in the boundary layer, and whether it can distinguish profiles such as that in **Figure 59** where the enhanced ozone is between 0.6–1.8 km aloft from cases where ozone is well mixed from the surface to the top of the boundary layer.

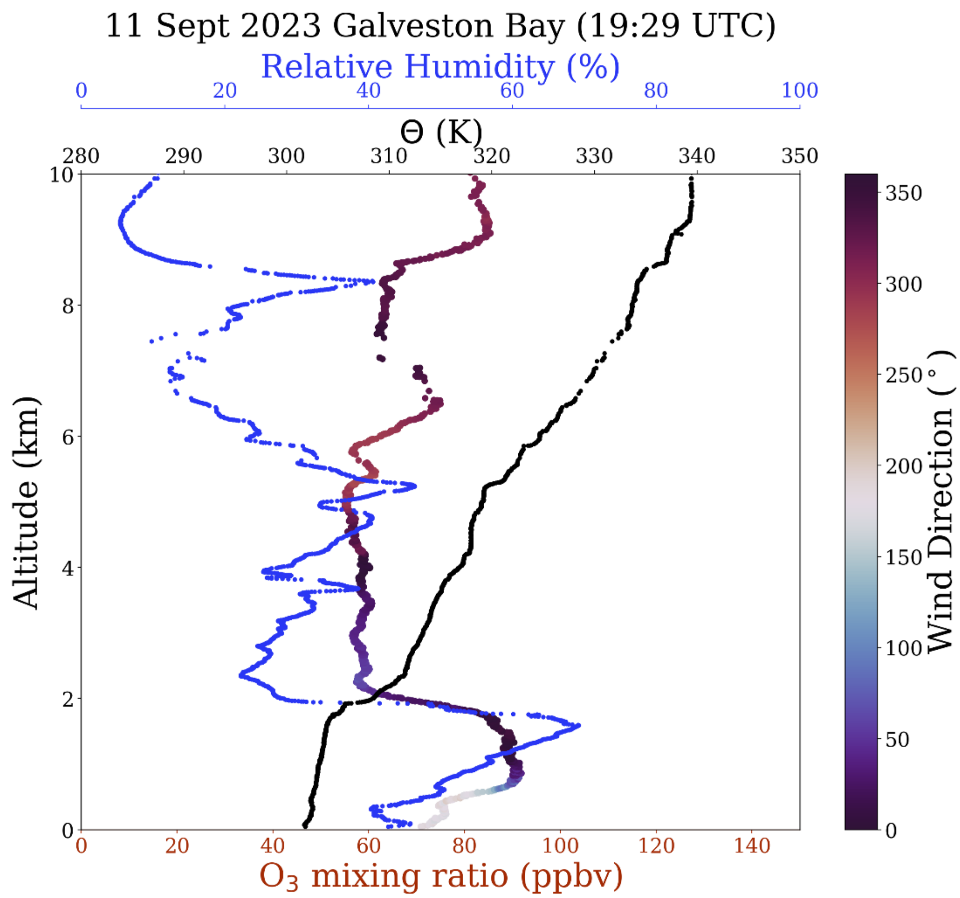


Figure 60. *Profiles of ozone (colored by wind direction), relative humidity (blue), and potential temperature (black) for an ozonesonde launched from Galveston Bay on September 11, 2023. The figure shows the first 10 km of the ascent.*

The ozone episode from September 17–19, 2023, occurred in post-frontal conditions (**Figure 61**). The three CAMS in the HGB region that exceeded the 8-hour ozone standard were along the coast with C1034 Galveston having the highest MDA8 [O3] of 83 ppbv. Surface winds at the C1034 Galveston monitor were out of the NE in the early morning and a sea breeze resulted in the winds shifting to being out of the SE in the afternoon (**Figure 61**).

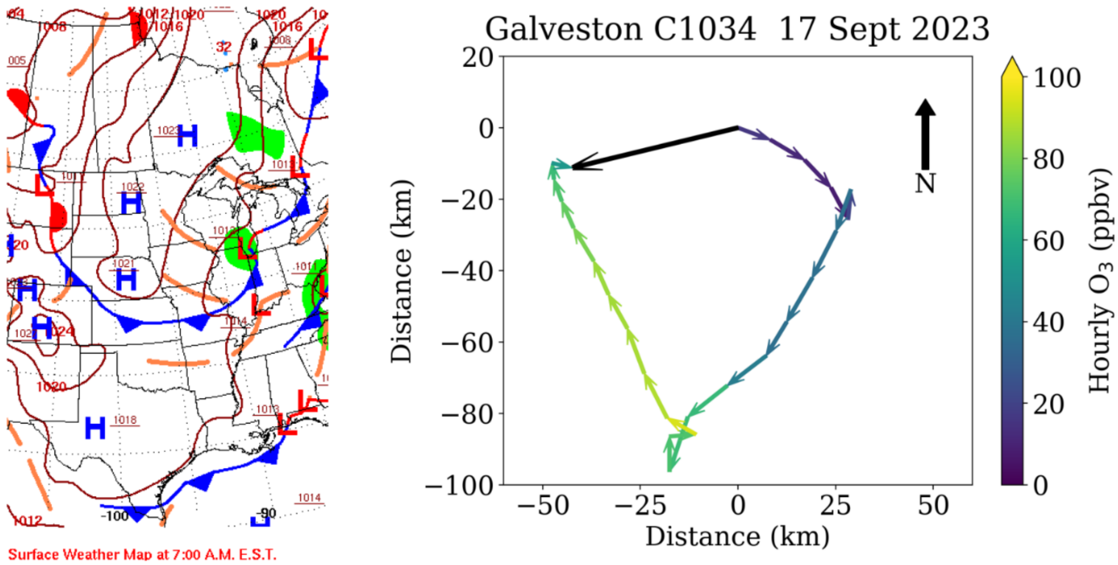


Figure 61. *Left: Surface weather map for September 17, 2023. Right: 24-hour wind run for the C1034 Galveston monitor on September 17, 2023, where the hourly wind vectors are colored by the ozone mixing ratio.*

Figure 62 shows the launch locations and first 3 km of the ozone profiles for each of the six ozonesondes launched on September 17. The early morning sonde from the University of Houston shows a shallow surface layer (~200 m) where ozone was titrated away and ~55 ppbv of ozone aloft in the residual layer. Two ozonesondes were launched from the MAQL-Sea offshore of Galveston Island in the Gulf of Mexico near the North Anchorage location for cargo ships.

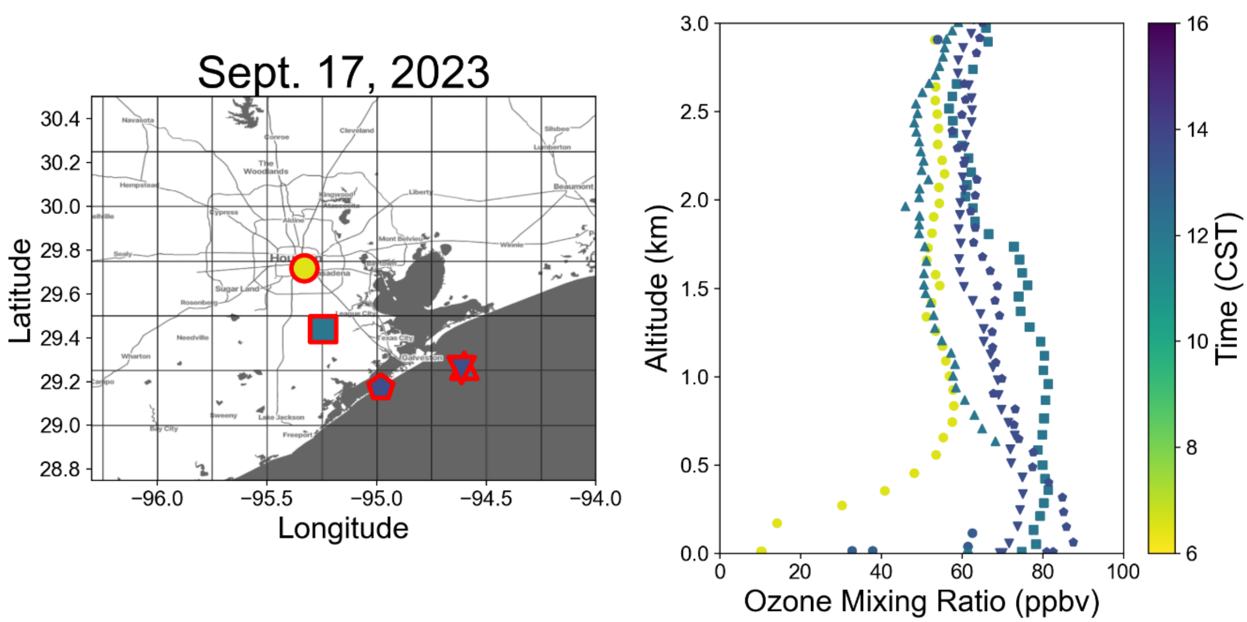


Figure 62. *Left: Ozonesonde launch locations on September 17, 2023. Right: Ozonesonde profiles for the first 3 km, colored by time of day. Launch locations are distinguished by shape.*

The late afternoon ozonesonde from Galveston Island shows a shallow layer from the surface up to approximately 0.4 km that has winds out of the ESE and an ozone enhancement, which is approximately 20 ppbv higher than the rest of the boundary layer (**Figure 63**). This low layer may be associated with a sea breeze and influences from air masses in the Gulf with elevated levels of surface ozone measured by the MAQL-Sea. Above that shallow layer, the winds had a more northerly component throughout the rest of the boundary layer.

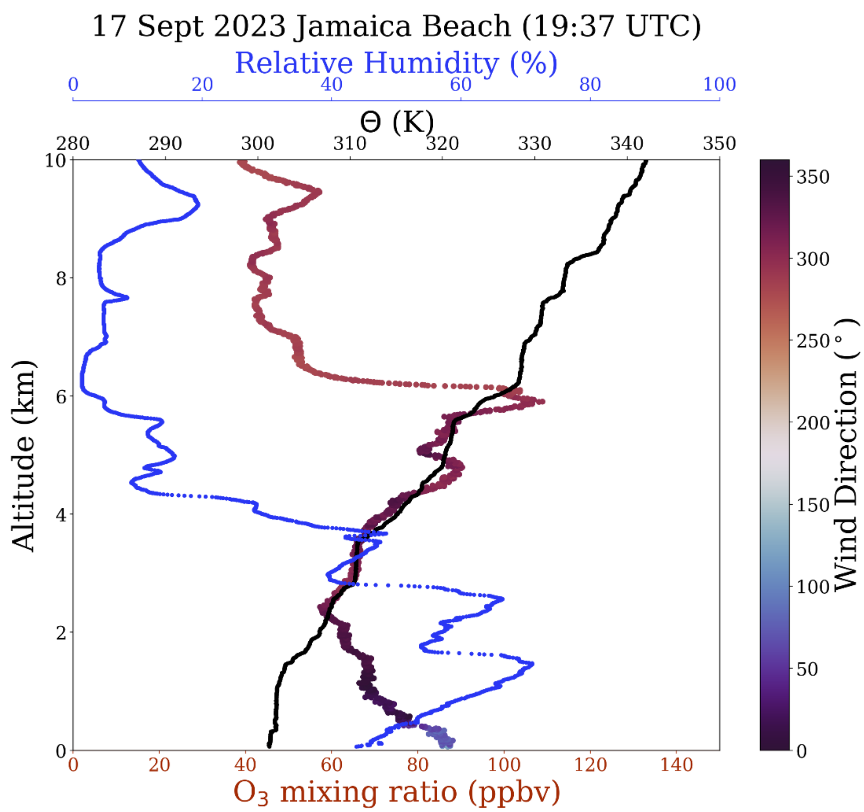


Figure 63. *Profiles of ozone (colored by wind direction), relative humidity (blue), and potential temperature (black) for an ozonesonde launched from Galveston Island on September 17, 2023. The figure shows the first 10 km of the ascent.*

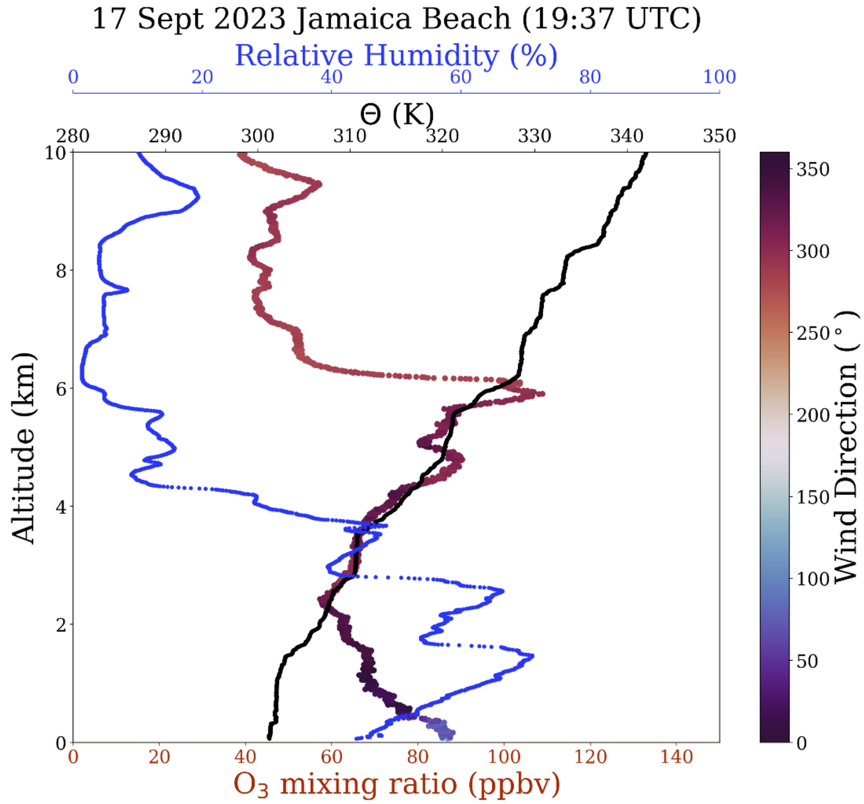


__Figure 64.__ Profiles of ozone (colored by wind direction), relative humidity (blue), and potential temperature (black) for an ozonesonde launched from Galveston Island on September 17, 2023. The figure shows the first 10 km of the ascent.

On September 18, winds at the C53 Bayland Park monitor (MDA [O3] of 97 ppbv) were near stagnant overnight, typical of post-frontal conditions, and were slow and out of the ESE during the afternoon (**Figure 65**). Wind speeds picked up slightly on the next day, with winds being out of the SE throughout the day at the C26 NW Harris Co. monitor (MDA [O3] of 89 ppbv).

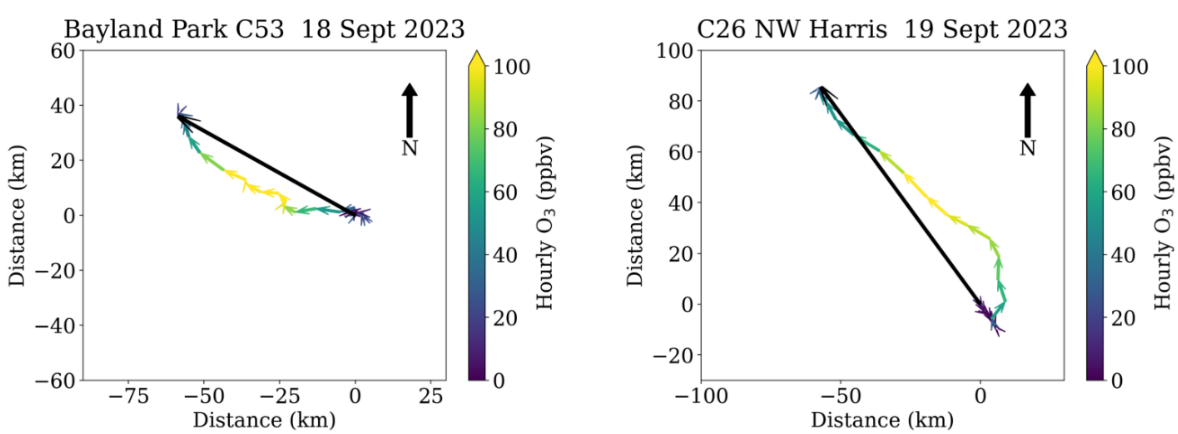


__Figure 65.__ 24-hour wind run for the C53 Bayland Park monitor on September 18, 2023 (left), and the C26 NW Harris Co. Monitor on September 19, 2023 (right), where the hourly wind vectors are colored by the ozone mixing ratio.

Figure 66 shows the launch locations and first 3 km of the ozone profiles for each of the four ozonesondes launched on September 18. While there is a data gap, the early morning sonde from the UH Coastal Center (pentagon) shows ozone was near 0 ppbv at the surface with close to ~60 ppbv aloft in the residual layer. Two ozonesondes launched from the MAQL-Sea in the Gulf of Mexico showed moderate ozone (60–65 ppbv) throughout the boundary layer. An afternoon ozonesonde from near Manvel showed more elevated levels of ozone in the boundary layer (~80 ppbv).

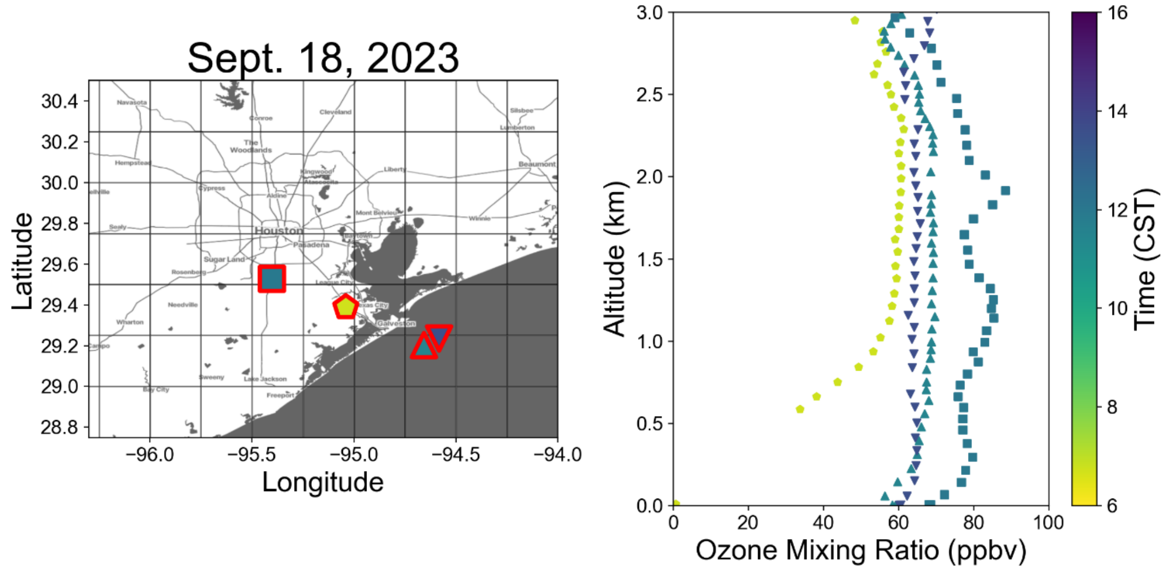


Figure 66. Left: Ozonesonde launch locations on September 18, 2023. Right: Ozonesonde profiles for the first 3 km, colored by time of day. Launch locations are distinguished by shape.

Figure 67 shows the launch locations and first 3 km of the ozone profiles for each of the four ozonesondes launched on September 19. There were two ozonesondes launched from the UH Coastal Center (pentagon), with the early morning sonde showing a steep ozone gradient near the surface. Two ozonesondes were launched in the Gulf of Mexico showed ozone as high as 70 ppbv in the boundary layer. The afternoon ozonesonde from the UH Coastal Center showed ozone as high as 75 ppbv in the boundary layer.

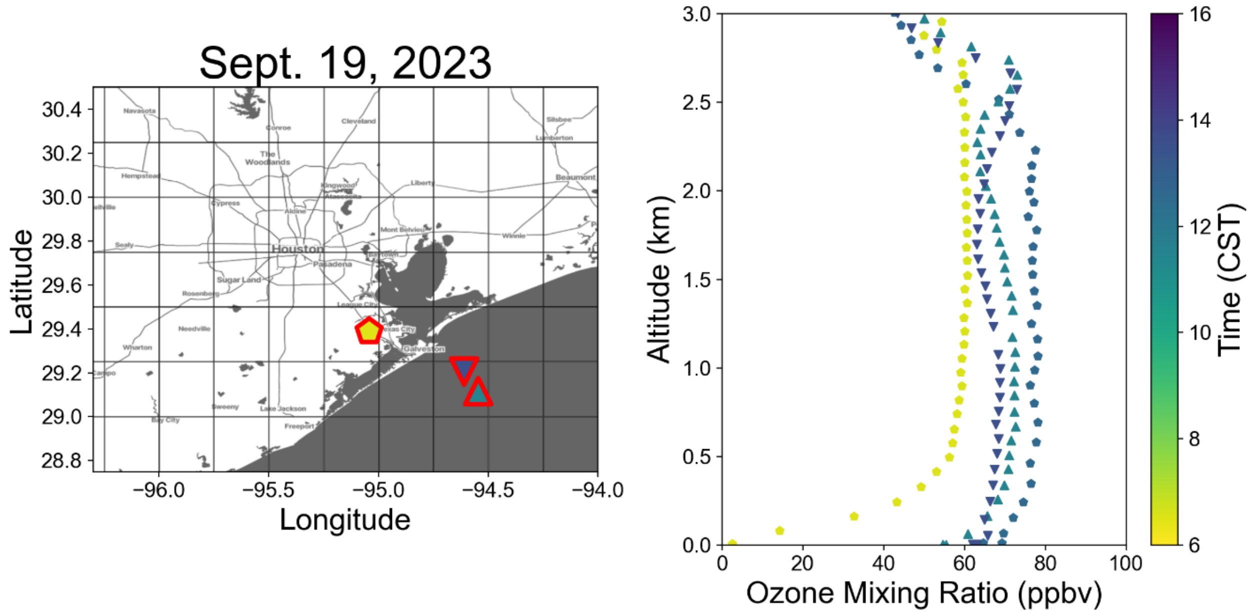


Figure 67. *Left: Ozonesonde launch locations on September 19, 2023. Right: Ozonesonde profiles for the first 3 km, colored by time of day. Launch locations are distinguished by shape.*

Figure 68 shows the launch locations and first 3 km of the ozone profiles for each of the four ozonesondes launched on September 27. There were two ozonesondes launched from the UH Coastal Center (pentagon) and two from MAQL-Sea in Galveston Bay. All of the ozonesondes were launched in the morning. The late morning ozonesonde from Galveston Bay shows an enchantment at ~1 km where ozone reaches 85 ppbv.

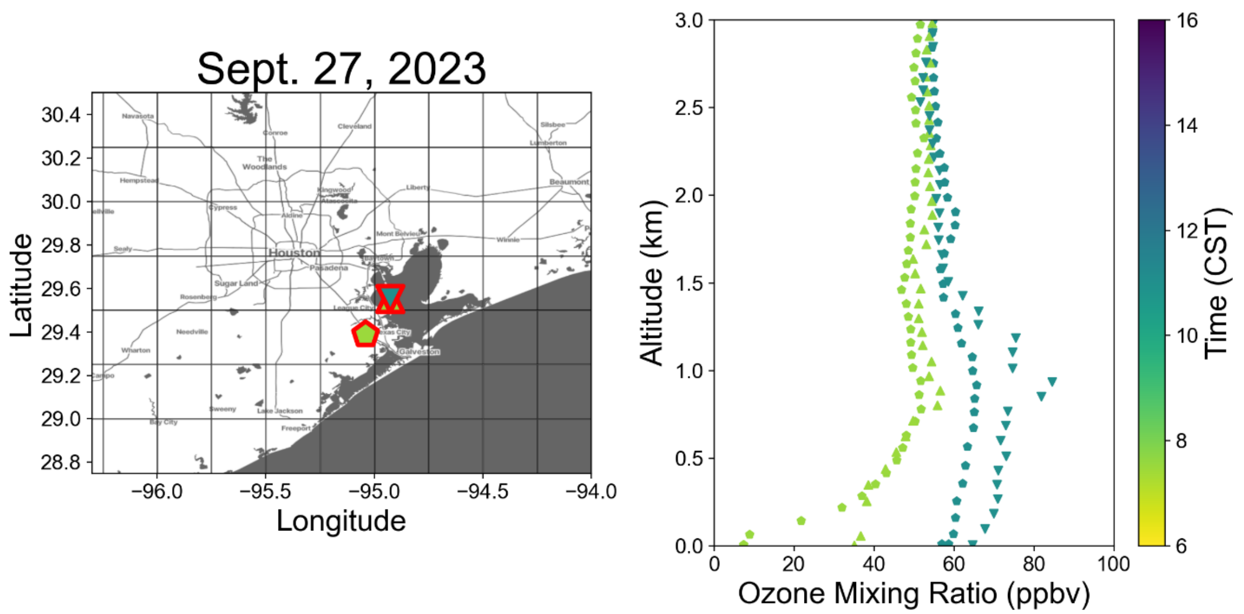


Figure 68. *Left: Ozonesonde launch locations on September 27, 2023. Right: Ozonesonde profiles for the first 3 km, colored by time of day. Launch locations are distinguished by shape.*

Figure 69 shows the launch locations and first 3 km of the ozone profiles for each of the five ozonesondes launched on September 28. There were three ozonesondes launched from Danbury (square) and two from Galveston Bay. All but the last sonde from Danbury were launched in the morning.

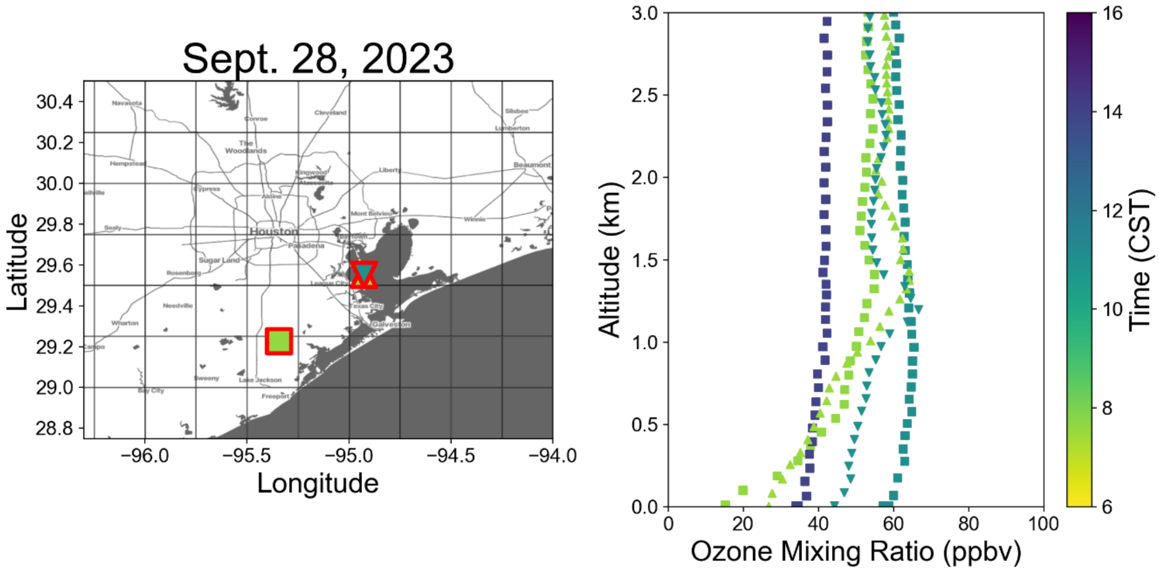


Figure 69. *Left: Ozonesonde launch locations on September 28, 2023. Right: Ozonesonde profiles for the first 3 km, colored by time of day. Launch locations are distinguished by shape.*

3.5 Task 7 – Guest Researcher Measurements

In recent years an effort was initiated to connect researchers in Texas with experience in mobile measurements and explore opportunities for collaboration. Through this process UH and Baylor began discussions with Dr. Natalie Johnson from Texas A&M University's School of Public Health. Dr. Johnson's research group operates a version of the PTR-MS which uses a time-of-flight mass spectrometer to resolve a vast number of compounds at a 1-second resolution and deploys this instrument in a mobile laboratory to evaluate atmospheric components in industrial areas to study the potential impacts on human health. These methods and tools are similar to those deployed by the UH and Baylor groups in the past and are viewed as complementary and supportive of the science.

This project represented an opportunity to collaborate with Dr. Johnson's group for the first time. Although there were no funds available to support the TAMU team directly, they graciously agreed to explore this relationship at no cost to the project other than those incurred by the integration of the instrument into the MAQL3 payload and additional support for Baylor personnel to act as operators of the instrument while in the field. As part of the agreement with TAMU, UH insured the instrument while it was in UH possession.

The collaboration was successful and large volumes of high resolution speciated data were generated and no major mechanical problems disrupted the measurements and the instrument was reinstalled in the TAMU mobile laboratory upon completion of the project. Some differences in the general approach to instrument operation and data handling were apparent and likely artifacts of the types of programs the two groups are traditionally involved in. As a result, future collaborations would likely include a funding aspect as well as greater discussions and preparation to better accommodate calibration processes and data handling needs. As the TAMU instrument is rarely operated continuously in a mobile lab, the data volume generated by its operation in the MAQL3 was significant and was too large to transfer over cellular data. The resulting data files reported thus far under this project are from the processing of each individual file, typically four per day. Because not all compounds were detected in each file, the columns within the files vary to some degree from one to another. Future work will include the standardization of file format and compilation of the individual files into a single file. One question which remains is whether data sets like these can be used with analysis tools such as PCA, PMF, or other machine learning tools to evaluate whether it is possible to identify unique characteristics within the measurements with respect to types of sources or activities or perhaps even specific sources themselves.

3.5.1 Quality Control / Quality Assurance

The following information was provided by the team at Texas A&M to describe their data processing and quality control procedures that were applied to the data collected under this project.

1. PTR-ToF-MS VOC Data Files
    a. Files with a sampling duration of at least 20 minutes were selected to be analyzed using the nontargeted analysis (NTA).
    b. As sampling was conducted continuously, the sampling duration of the VOC files ranged from 20 minutes to 5 hours and 33 minutes.
    c. A total of about 98 VOC files were further analyzed.
2. NTA
    a. Mass Calibrations
        i. The averaging spectra for all files fell within the range of 10 – 130 to achieve an RMS Mass Error of less than .001. However, there were some files where the averaging spectra was set to 130 but still surpassed an RMS Mass Error of .001. For files such as those, the datapoints with an RMS Mass Error greater than .001 shall be replaced with a value of 0.
    b. Peak Analysis
        i. After setting the signal-to-noise ratio to 5, the compounds with a mass of 45 or more were selected for further peak analysis.

ii. Molecular formulas are assigned to the peaks if there is at least a 90% correctness. The concentration data of these compounds are exported into a CSV file.

c. Exported data will contain the following: Absolute Time, Relative Time, Cycle, and VOC concentration data in parts per billion (ppb) for each compound.

   i. The chemicals in the headers have 1 additional hydrogen added to the chemical formula as well as the peak mass. When the PTR detects a compound, it will protonate the compound in the air sample.

      1. Header: (C[12]6H[1]7) → C6H6 (Benzene)

4. CONCLUSION

This project saw the successful deployment of two new tools to collect more comprehensive atmospheric data sets. The MAQL3 complements the small MAQL1 and medium MAQL2 and allows for a much larger instrument payload at a scale not previously available. Lessons learned from this project have led to significant improvements in the platform such as a walkthrough passage between the cab and lab space to increase functionality, the addition of an auxiliary axle to increase the payload and maximum legal gross weight, and the recording of additional housekeeping parameters such as redundant GPS and a relative wind measurement to indicate times which could be affected by self-sampling.

Similar to the great strides and opportunities presented by MAQL3, the MAQL-Sea is also a great step forward in capacity. With a large air conditioned cabin it is possible to house more instruments in traditional racks, similar to those used on research aircraft. The resulting measurement capabilities more closely resemble previous MAQL1 payloads than those from the pontoon deployed in 2021 and 2022. The increased fuel capacity and speed make it possible to repeat sampling routes multiple times a day and the design of the hull allows the MAQL-Sea to operate in rougher water as well as in the Gulf of Mexico. This project reached approximately 20 miles offshore however with increasing experience and familiarity with the platform we intend to reach up to 50 miles into the Gulf, the current limits of our insurance policy.

Although not exhaustive, Section 3 described several highlights of the measurement campaign which have the potential to be useful to the TCEQ through a more detailed analysis. A more in-depth analysis of these results may yield insights that can support decision making and identify knowledge gaps that can be addressed by future studies and modeling efforts. It may also be beneficial to tailor these analyses to address the areas of highest interest to the TCEQ or to potentially divide analyses into separate but logically grouped projects.

Similarly, future air quality studies may choose to target specific processes which would allow a tailored instrument package, measurement platform, or target meteorological condition. These focused campaigns could also explore questions such as volatile consumer products, marine emission inventories, or meteorological dynamics such as the Galveston Bay breeze and do so at a reduced cost relative to larger comprehensive studies with many facets. These studies may also allow for the inclusion of one or more groups from other universities such as Texas A&M in College Station or Corpus Christi. Additionally, although the mobile laboratories are well suited for spatial characterization they are also very useful in that they can be placed in strategic locations to address questions which benefit from an Eulerian approach. With multiple mobile laboratories with significant payloads, i.e. MAQL2 and MAQL3, sites can be established in source and receptor areas to complement the existing monitoring network. Depending on the scope of the measurements, these types of studies may be able to operate for longer time periods than a mobile campaign for a given amount of funding.

Likewise, future studies will be able to leverage the new research facility being constructed at UH as a replacement for the aging Launch Trailer which is being displaced from its site on the main campus due to an expansion of the Law School. This new site at the UH Technology Bridge is roughly 100 m from the warehouse space for the UH field platforms and new balloon launch location. The ~750 sq. ft. lab will have adequate power and space to host intensive campaigns and utilize a 10 m multi-level walk up scaffold platform as well as four dedicated RV power panels for powering stationary mobile/portable labs or to serve as a secure overnight parking space from which to base for mobile campaigns. The growing capabilities within the Texas university atmospheric research space is growing and is approaching a point where it may be possible to evaluate many processes without the need to fund groups which may require larger travel budgets.

One such targeted meteorological study could deploy the drone. Although the drone's campaign was cut short after being damaged, the data show great promise for helping to understand the transition from a stable nocturnal inversion to the development of a convective boundary layer, particularly in an environment such as the UH Coastal Center where these phenomena can be better isolated from the complex built environment in and around campus or Battleground and the associated turbulence from winds and urban or industrial heat islands. The groups hope to continue to explore the application of the drone to expand the useful measurements to also include NO_2 and a more robust SO_2 instrument in addition to O_3, VOCs, and meteorology.

The morning boundary layer dynamics have also been observed in ozonesonde launches, particularly in or downwind of urban areas where strong positive vertical gradients in O_3 have been seen. New technology being developed with UH, SEU, and private partners is expected to yield an affordable method of measuring NO_2 from balloon payloads. This measurement would complement O_3 and allow for a better understanding of these early morning gradients and to what extent they can be explained by titration to NO_2 vs. deposition, horizontal transport, or other processes. The results could be used to shed light on the early morning conditions which precede ozone event days or episodes and help constrain modeling efforts to recreate the conditions and delve into deeper chemical and physical processes.

A longer-term goal may be to reexamine the potential to establish one or more O_3 lidars in Houston or other Texas cities. The most recent version of the Jet Propulsion Laboratory's Small Mobile Ozone Lidar (SMOL) has been developed to use commercial off-the-shelf components as a way to keep the construction costs low, in some cases below $100k. While they are unable to run continuously 24/7/365, they can be used continuously for multiple consecutive days similar to the larger O_3 lidars deployed by NASA and NOAA, but with greatly reduced complexity. The existing SMOL systems have been deployed in the Los Angeles area, New York, and are planned for several future deployments. It may be possible to attract one of the systems to Houston for an evaluation period, and if successful, pursue options for funding a longer-term program, potentially as a cost share between one or more organizations or funding agency.

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6. Appendix A: Task 3 – Mobile Air Quality Measurements daily figures and field notes

Included in this Appendix are daily figures which summarize a selection of the measurements aboard MAQL3. These are not intended to be comprehensive but should provide a quick overview and allow for quick comparisons between days as the scales are consistent day to day. Lightly edited field notes are also included to provide context for the data and should be useful for subsequent analysis. These notes were edited for clarity and may still contain typos as they were initially typed while in motion. They reflect the observations made at the time and references to sources are intended to help identify the geographic region where the measurements were collected and not necessarily to link a specific source to the observations. Most times these were read from nearby signage. Days without notes and spatial plots were stationary for calibrations, maintenance, crew rest, or weather reasons.

September 1, 2023

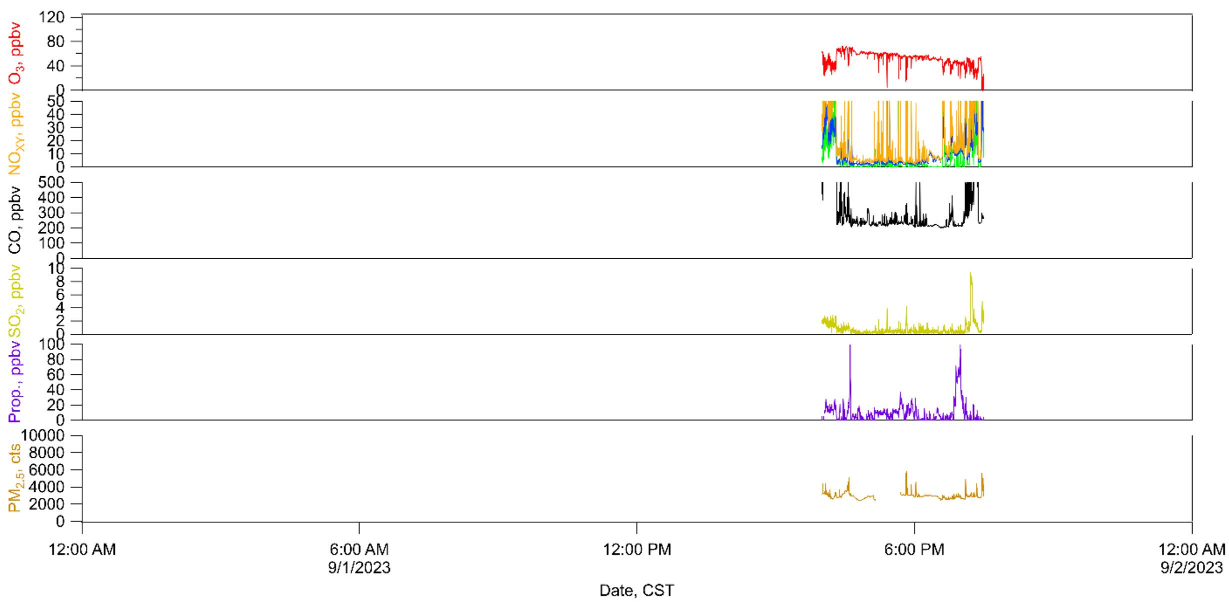

Figure 70. *Time series for selected measurements aboard MAQL3 for September 1, 2024.*

Time	Notes for September 1, 2023
08:30 CST	Started multipoint calibration
09:40 CST	Starting NO_2 calibration
11:21 CST	Starting NO_2 calibration (launch trailer tank)
13:00 CST	Turned on HCHO zero valve
13:05 CST	Turned on zero for VOC line
14:35 CST	Turned on isoprene cal gas
15:10 CST	Started power transfer to go mobile. TG (trace gas) line is being zeroed.
15:28 CST	Noticed zero air generator was powered off. The power cable was not pushed in all the way.
15:48 CST	Outside of ERP 14 to set up the ceilometer.
	Heading to Marina
15:55 CST	Heading towards I45 S to get onto the highway
16:22 CST	Off of highway, less traffic. Local road
16:33 CST	At the traffic light, smells like food. Smaller vehicles.
16:36 CST	Strong smell (sea water?) Peak in alkenes
16:40 CST	Waiting at the gate to enter the marina.
	Stationary at Marina
16:44 CST	Drove in, did a U-turn, and parked near the gate.
	Heading to La Porte
17:57 CST	Heading to La Porte, getting out of the marina.
18:00 CST	Heading northbound.
18:02 CST	On the side road for 146 road
18:06 CST	Drove over a bumpy road.
18:10 CST	Methane increasing, and winds are in the south. Near forest villa home park
18:12 CST	Exiting onto Spencer Street. Self sampling
18:15 CST	Right onto Sens Rd. Some self-sampling, still increase in methane
18:17 CST	Left turn onto H street. A slight peak in SO_2.
18:26 CST	Backing into a parking spot.
	Electrical issues at La Porte, heading to ERP14.

September 2, 2023

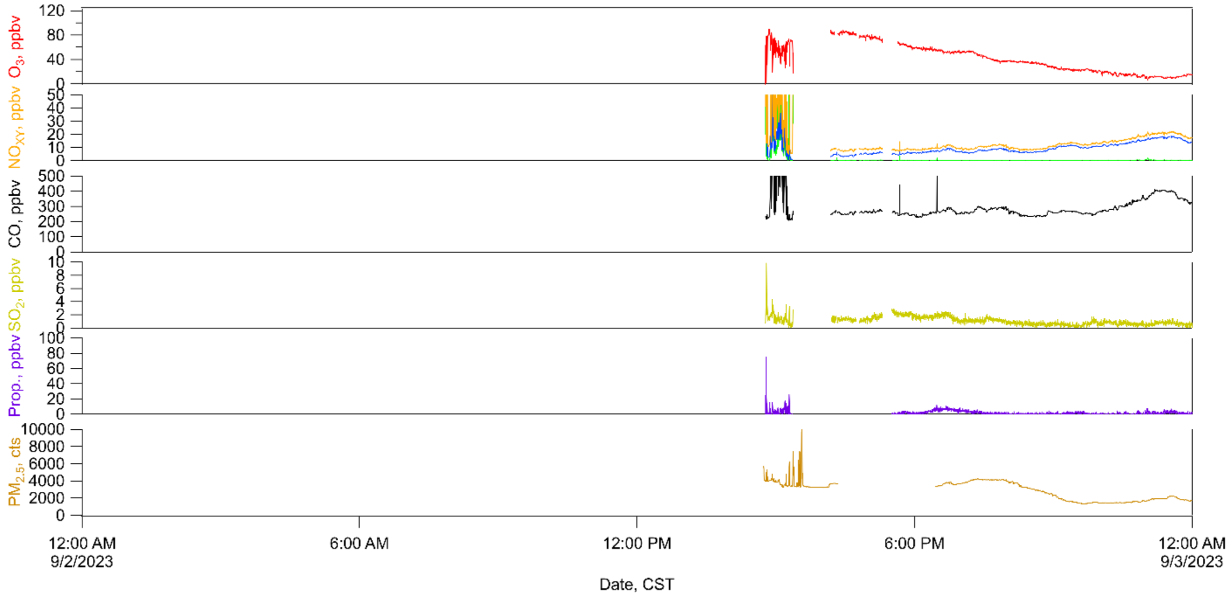

Figure 71. *Time series for selected measurements aboard MAQL3 for September 2, 2024.*

Time	Notes for September 2, 2023
09:30 CST	Approx time started calibration for heated VOC line starting with zero
10:00 CST	Approx time started calibration for isoprene on heated VOC line.
10:41 CST	Issues with flow for isoprene cal
11:11 CST	Started up isoprene cal again
14:44 CST	Heading to Aldine for BC2 intercomparison while La Porte power connector is getting swapped.
15:00 CST	The ceilometer is working but getting warning messages about window contamination
15:10 CST	Exiting highway.
15:11 CST	Taking a left onto Aldine Mail Route Rd. Some traffic.
15:15 CST	Turning into the high school library.
15:16 CST	Backing up into Aldine site, self-sampling. High NOx.
15:19 CST	Parked at the site.
15:21 CST	Self-sampling, zeroing TG (trace gas) and HCHO lines
	Spent the afternoon at Aldine planning calibrations. Calibrations will be done tomorrow.

September 3, 2023

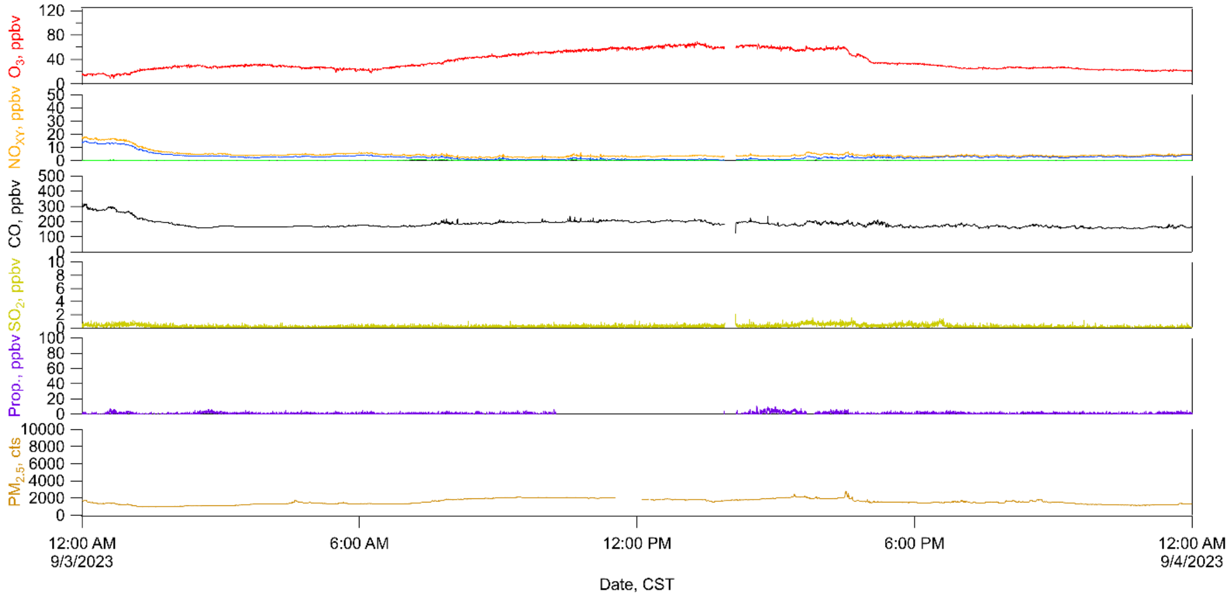

Figure 72. *Time series for selected measurements aboard MAQL3 for September 3, 2024.*

Time	Notes for September 3, 2023
10:03 CST	Arrived and started zeroing HCHO.
10:12 CST	Refilled both hantzch and stripping solution
10:15 CST	Zeroing HCHO.
10:30 CST	Approx time zeroing heated VOC line. 2V zero air through HCHO cal system.
10:34 CST	Approx time 5V on Propene tank UH
10:38 CST	Prakash is swapping the Picarro line from the calibration setup to the connection at the manifold. Checking to see if this changes the response of the PTRMS.
11:03 CST	Finished propene calibration + long zero
11:04 CST	Starting ethene calibration (UH tank).
11:33 CST	Starting BTEX calibration PTRMS
11:40 CST	4V next level on HCHO
11:49 CST	2.5V for HCHO cal
12:00 CST	4V on BTEX cal.
12:01 CST	1V for HCHO cal
12:12 CST	0.25V for HCHO cal
12:15 CST	High point span of isoprene PTRMS
12:22 CST	0.125V on HCHO cal
12:33 CST	0V on HCHO cal
12:47 CST	Starting multiblend for RAD. 5V cal and 5V ZA.
12:59 CST	4V cal on multiblend for RAD
13:00 CST	3V cal on multiblend for RAD
13:03 CST	2V cal on multiblend for RAD
13:06 CST	1V cal on multiblend for RAD
13:10 CST	.25V cal on multiblend for RAD

Time	Notes for September 3, 2023
13:15 CST	Started ethene calibration on RAD instrument
13:21 CST	Level 4V
13:25 CST	Level 2V
13:28 CST	Level 0.5V
13:31 CST	Level 0V
13:35 CST	Started propene calibration on RAD instrument
13:38 CST	Level 4V
13:41 CST	Level 2V
13:44 CST	Level 0.5V
13:47 CST	Level 0V
13:53 CST	Zeroing TG line
14:00 CST	High span on multiblend on TG line
14:06 CST	Zeroing TG line
14:08 CST	Ambient on TG and VOC lines

September 4, 2023

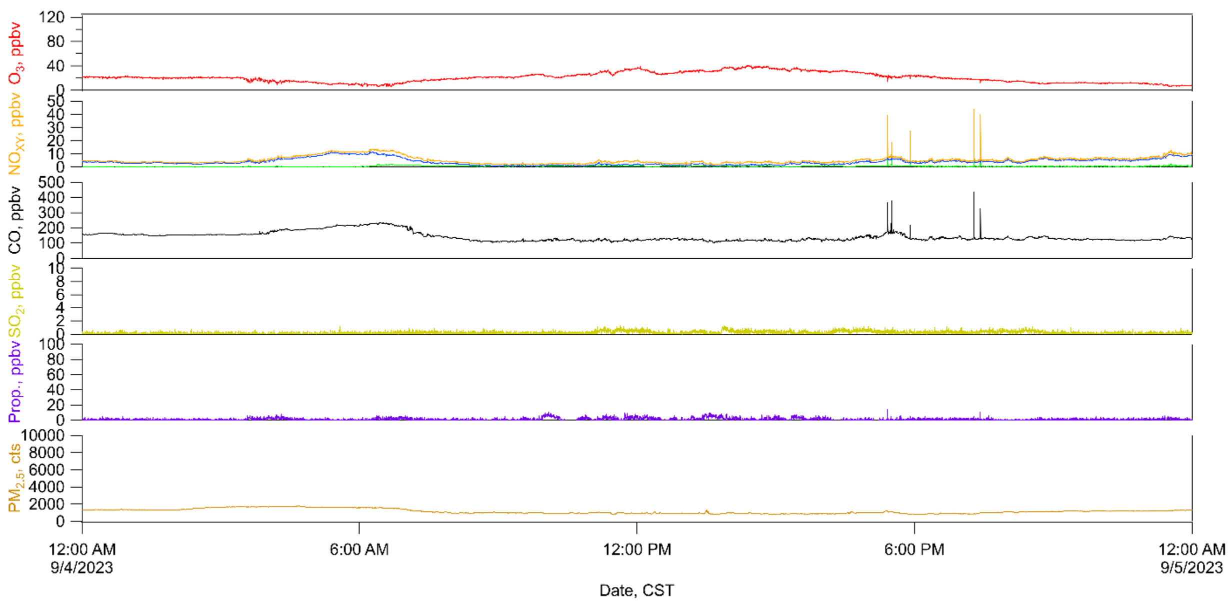

Figure 73. *Time series for selected measurements aboard MAQL3 for September 4, 2024.*

September 5, 2023

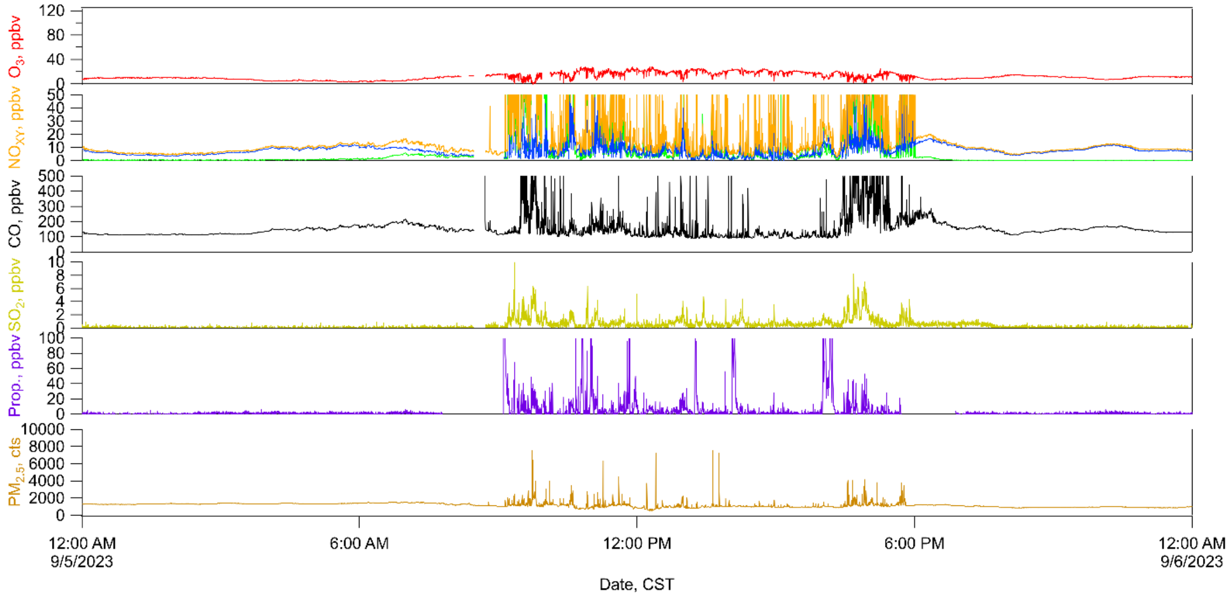

Figure 74. *Time series for selected measurements aboard MAQL3 for September 5, 2024.*

Time	Notes for September 5, 2023
07:58 CST	Turned on ZA for HCHO
08:00 CST	Calibrating isoprene
08:30 CST	Added more stripping solution
08:12 CST	O_3 span (~100 ppbv)
08:20 CST	Stopped O_3 span.
08:21 CST	Closed O_3 cal valve.
08:25 CST	Finished calibration of PTRMS running ZA
08:26 CST	Working on Picarro calibration, opening lines
08:28 CST	Zeroing TG line
08:29 CST	Closing HCHO valve to make sure we're getting enough zero air to TG line
08:36 CST	Started generator
09:04 CST	Manual zero for RAD. Delta from ambient
09:06 CST	Ambient for RAD
	Driving to La Porte for source sampling measurement
09:25 CST	Driving out of Aldine.
09:37 CST	Seeing vehicle emissions lots of SO_2.
09:47 CST	Passing bridge on highway over to La Porte.
09:54 CST	Climbing HCHO getting into La Porte.
	First pass at Battleground/independence Pkwy (northbound)
10:02 CST	Exited onto battleground
10:04 CST	Winds are from the south.
10:05 CST	Traffic emissions are settling. Rad baseline slightly higher than aldine?
10:09 CST	Taking a left into Tidal Rd. Increase in xylene

Time	Notes for September 5, 2023
10:10 CST	RAD increased to 900 counts and PTRMS getting an increase
10:12 CST	Isoprene is higher, seeing in both PP1 and PTRMS. Inside tidal road
10:16 CST	Flares up ahead. Not seeing much in the measurements. Likely due to winds.
10:17 CST	Can smell things.
10:18 CST	More smells, passing by Lubrizol 4, not seeing much in VOC and TG. Back end of Tidal Rd.
	Slow drive eastbound on the Pasadena Fwy service road.
10:20 CST	Taking a left onto the service road of the highway.
10:22 CST	Rain clouds on the west side.
10:27 CST	Starting to rain as we head east on the service road.
	Second pass at Miller Cutoff (northbound)
10:28 CST	A left onto Miller Cutoff Rd. Stuck in traffic at the 3-stop intersection. Entry at gate one jamming tucks.
10:35 CST	Traffic cleared crossed over, but now stopped again at Miller. Seeing NOx from traffic. - multiple trucks in front. Source sampling
10:37 CST	Traffic cleared driving into the cutoff road.
10:40 CST	Ch4 increase passing by pipelines
10:41 CST	Increase in RAD by almost 2000 counts.
10:43 CST	Going over a railroad.
10:44 CST	Increase in RAD passing by Oxyvinyls.
10:47 CST	Passing CIMA staging ethylene, Methane peak and propene increase, RAD steadily increase
10:48 CST	HUGE peak in RAD over 10,000 counts. Before the VoPak Guard Shack.
	Third Pass at Miller Cutoff (southbound)
10:52 CST	Taking a left into a parking lot to check next route and finding route to head back. Self sampling
10:55 CST	Heading back onto miller cut off southbound.
10:58 CST	Passing Texas Molecular TM Deer Park Services. Seeing an increase in propene and RAD. Passing by enterprise products and Gate 4.5 Total Energies.
11:02 CST	Passing by INEOS and seeing increase in methane (4ppm) and HCHO (6ppb)
	Love's gas station break.
11:04 CST	Taking a right getting into Love’s travel stop. Inside gas station.
11:05 CST	Peak in PP1, but PTRMS. Pumping gas and parked for restroom breaks
	Fourth Pass: heading out of Loves northbound on Independence Parkway.
11:44 CST	Heading onto Independence parkway northbound.
11:47 CST	Seeing increase in methane. And increase in RAD by INEOS
11:29 CST	Increase in RAD seeing increase in HCHO in Picarro.
11:53 CST	Turning into overflow parking to make a turn.
	Fifth Pass: heading southbound on Independence. Winds have increased coming in from southerly
11:57 CST	Right onto tidal rd.

Time	Notes for September 5, 2023
11:58 CST	Passing by Valvoline, seeing xylene, rad seeing some enhancement (150 counts). Smells.
12:00 CST	Stopped at railroad crossing. Previously saw an enhancement in methane
12:02 CST	Rights side of us water flowing out of ground.
12:08 CST	Stickier road but not seeing RAD, but some increase in methanol.
	Heading to Bayport
12:15 CST	Heading west on services road towards Bayport. Seeing some methanol and inc in rad count.
12:17 CST	Few min before there was a train passing with VOC peaks and some NO_X. No CO
12:18 CST	Left onto Sens Rd (southbound) bumpier road.
12:22 CST	HCHO has been dropping from Battleground area.
12:24 CST	A small peak in RAD at stop light. And saw VOCs at PTRMS.
12:25 CST	Passing by refineries in Bayport. + bump in road (railroad tracks.
12:26 CST	A small bump in methane rising as we're passing Palmer logistics. -high hydroxyacetone.
12:29 CST	Very high peaks of methanol as we pass LyondellBasell.
12:30 CST	Peak in Xylene. Passing small ponds by the refineries.
12:32 CST	Smells, bumpy roads.
12:33 CST	Passing by monument chemical peak in benzene, small peak in methane.
12:36 CST	Right onto Red Bluff Rd. Consistently seeing elevated benzene.
12:37 CST	Seeing drop off of benzene.
12:39 CST	Driving into some rain. Methanol is climbing.
12:42 CST	Right onto Genoa Red Bluff Rd. Methanol is dropping down.
	Heading to Baytown
12:46 CST	At stop sign Fairmont Road. Still raining.
12:48 CST	Spike in acetone as an SUV passed the MAQL3.
12:1 CST	Stopped at Driftwood.
12:56 CST	Very narrow peak of VOCs, RAD (alkene), and methane.
12:57 CST	Taking a left onto SH146.
12:59 CST	SO_2 increase on the highway. Several ppbv on Highway 146. Seen similar previously.
13:01 CST	Crossing over the ship channel on SH149, passing by Exxon on our left
13:05 CST	Exit highway taking left onto W. Texas.
	First Baytown loop
13:06 CST	Left onto Airhart Rd.
13:08 CST	Passing ExxonMobil complex.
13:10 CST	Taking right onto Market Street (not much gases or VOCs yet.)
13:12 CST	Right onto Bayway Drive. Crossing railroad. Running northwest.
13:16 CS	High RAD counts, not seeing PTRMS propene.
12:17 CST	SO_2 is climbing. Rad is climbing down but pretty high.
12:23 CST	Right at Baker Rd.
12:25 CST	Increase in SO_2 peaked close to 9 ppbv
12:27 CST	Stopped at Decker
13:31 CST	Stopped at Rollingbrook. Seeing noise in the Picarro HCHO.

Time	Notes for September 5, 2023
	Second Baytown loop
13:32 CST	Taking right onto Airhart Rd.
13:35 CST	Waiting for the train in front. Checking out the local park on Airhart in front of Exxon facilities.
13:36 CST	Driving into the local park. Parked railroads to our right.
13:57 CST	Continuing on the second pass. Passing bumpy railroad.
13:59 CST	Right onto Market Street.
14:01 CST	Right onto Bayway Drive. Seeing a spike in Xylene,
14:04 CST	Peak in RAD of almost 3400 counts, no peaks in PTRMS, and also an increase in SO_2. Methane peak of 2.4 ppm
14:15 CST	Observed peak in isoprene at 14:07 in both PTRMS and PP1.
14:16 CST	Same increase in propene on PTRMS.
14:17 CST	Still seeing SO_2 climbing. Same as last. Driving along the service road near ExxonMobil plant.
14:21 CST	Right onto Airhart Dr.
14:24 CST	Left into the park for a planning call.
	Third Baytown loop
15:52 CST	Heading out towards the final lap for the day.
15:54 CST	Left onto Airhart Rd. Bumpy rd.
15:57 CST	Right onto Market St.
16:00 CST	RAD high, small amount of propene, xylene, benzene,
16:04 CST	Heading back to Aldine.
	Heading back to Aldine
16:07 CST	Headed into a parking lot, making a turn to go back out.
16:08 CST	Heading back, westbound on Bayway drive towards high RAD peak
16:13 CST	Peak of RAD and methane increase. Some peak points in methane. Same peaks as previous. Some propene.
16:16 CST	Left lane onto Market Street
16:23 CST	Right onto Decker to get onto the highway.
16:31 CST	Sitting in traffic. Hcho increasing with the usual traffic
16:46 CST	Peak in acetone, propene, HCHO. With increasing SO2.
16:58 CST	Behind diesel trucks.
17:15 CST	Changing to different highway.
17:17 CST	Exiting highway.
17:18 CST	Right onto Lauder.
17:28 CST	Right turn into the high school to get to the Aldine site.
17:30 CST	Parked and waiting for jimmy to pull out his car.
17:43 CST	Zeroing HCHO

September 6, 2023

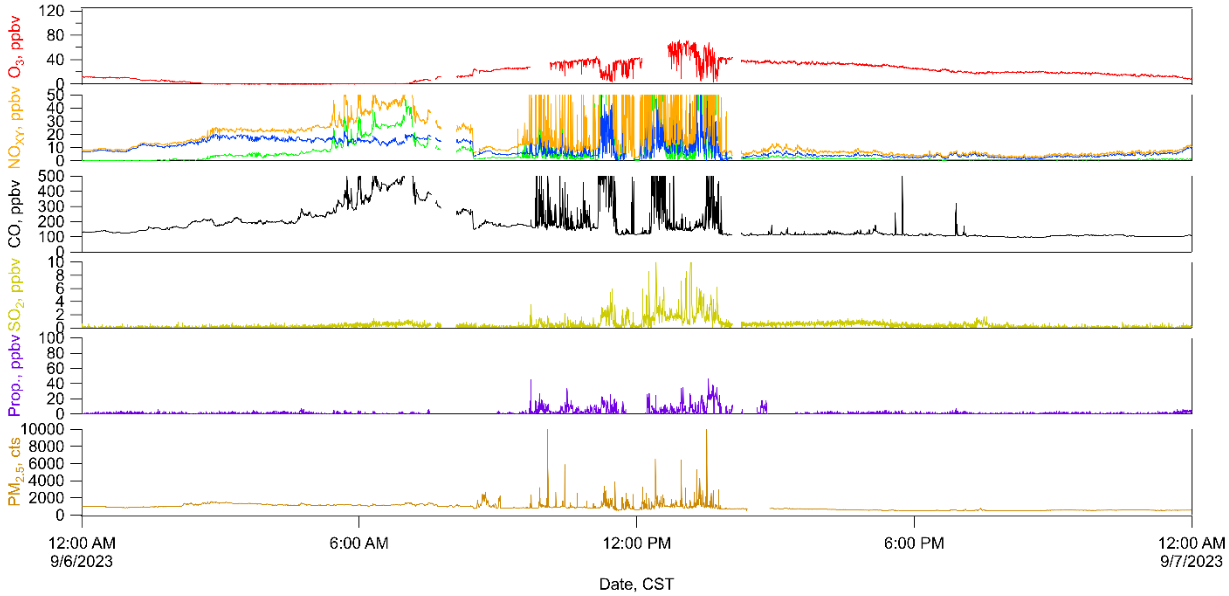

Figure 75. *Time series for selected measurements aboard MAQL3 for September 6, 2024.*

Time	Notes for September 6, 2023
07:28 CST	Turned on zero air system
07:31 CST	Turned on manual zero air from RAD
07:33 CST	ZA running through the TG line and O_3 cal
07:38 CST	Stopped TG and O_3 zero
07:46 CST	Starting high point for TG calibration
07:53 CST	Filled up on HCHO solutions
07:54 CST	Turned off TG high point
07:57 CST	Turned back on the HCHO and RAD ZA valve
08:06 CST	Turned TG valve off now doing true zero
08:26 CST	Turned on zero air
	Drive around Airport
09:48 CST	Heading out of site. Northbound on John F Kennedy
09:52 CST	Aldine Bender intersection. Trucks and fleets next to us.
09:58 CST	Taking a left onto greens. Shuttle traffic and cars. Increase in HCHO several minutes ago.
09:59 CST	Driving slow adjacent (south side of the airport) seeing some enhancement of NOxy
10:04 CST	Stopped at Aldine Westfield, to take a right. Traffic in front of us
10:10 CST	Passing by facilities with big drums of jet fuel. Fuel farms. Trimethyl benzene peaks
10:14 CST	Overall enhancement in HCHO levels.
10:15 CST	Taking a right onto East Richey Rd. Seeing slightly less TG, but also a bit less traffic
10:19 CST	Right turn on FM 1960

Time	Notes for September 6, 2023
10:26 CST	Brown truck, cause lot of NOx, co, and HCHO, and SO_2.
10:29 CST	Slightly further from the airport seeing less background in NOx. Northeast of the airport.
10:30 CST	Right turn heading south of the airport. Seeing gradual enhancement in rad
10:33 CST	Stopped at the stop sign. Waiting on traffic. Getting local emissions.
10:36 CST	Smaller road on Lee. Not much traffic.
10:40 CST	The road has a lot of trees
10:45 CST	On bumpier road.
10:49 CST	Stopped at the bumpier road at the intersection of JFK. The area has a relatively lower NOxy background relative to the west side of the airport
	Drive back to Aldine's site to grab Baylor's vehicle.
11:00 CST	Turning into the parking lot
11:05 CST	Waiting for Prakash, will head to campus next to install
	Heading to ERP to swap out O_2 tanks.
11:09 CST	Right onto Aldine Mail Route Rd.
11:13 CST	Heading onto the highway. Seeing an increase in HCHO.
11:14 CST	On the highway, increasing HCHO and traffic emissions including NO_{XY}, SO_2, CO, and aerosols.
11:28 CST	Getting onto I45 Southbound.
11:31 CST	Off of highway.
11:36 CST	Drove into ERP.
11:55 CST	Changed O_2 tanks
12:00 CST	Seeing self sampling of diesel generator, lower CO, high SO_2, and NOxy.
	Heading to Channelview for measurements.
12:15 CST	Heading to a gas station to pick
12:17 CST	Heading on to the service road of I45 southbound getting out from self sampling
12:29 CST	I10 Eastbound. Seeing traffic signal, is still increasing HCHO. Traffic emission, high CO, some SO_2, relatively lower NOx(compared to diesel generator)
12:36 CST	Exiting on Sheldon towards a pilot
12:40 CST	Had to set O_3 to sample mode.
12:43 CST	Heading into a gas station, increasing HCHO in this region.
12:55 CST	Heading out of gas station after small break.
12:57 CST	Right onto Mark Street.
13:00 CST	Spike in xylene near some of the commercial shops. Roads are a bit bumpy.
13:02 CST	Taking a drive into a residential area/park (lakeside drive).
13:07 CST	As we drive closer to K-Solv building seeing increase in VOCs on the PTRMS. Smells like solvents. HCHO also increasing. Slow driving due to electrical company out and fixing lines.
13:11 CST	Hazmat shipping company Stolt/Farmer ???
	Driving back to the gas station to fuel up and go to La Porte
13:14 CST	Driving back onto Market Street.
13:16 CST	Parking to fuel.

Time	Notes for September 6, 2023
13:25 CST	Fueled up and heading to La Porte site
13:32 CST	On highway I10 westbound -> Sam Houston tollway. Traffic emissions.
13:39 CST	Driving onto La Porte freeway eastbound. Normal traffic emissions
13:44 CST	Butane peaks, some VOC peaks as we head close to Miller Cut off Rd.
13:47 CST	Right onto Sens Rd. HCHO is lower, getting on the other side of the bay breeze.
13:52 CST	Arrived at the La Porte gate
14:05 CST	Started zeroing trace gas line and O3 line
	Started HCHO zero.

September 7, 2023

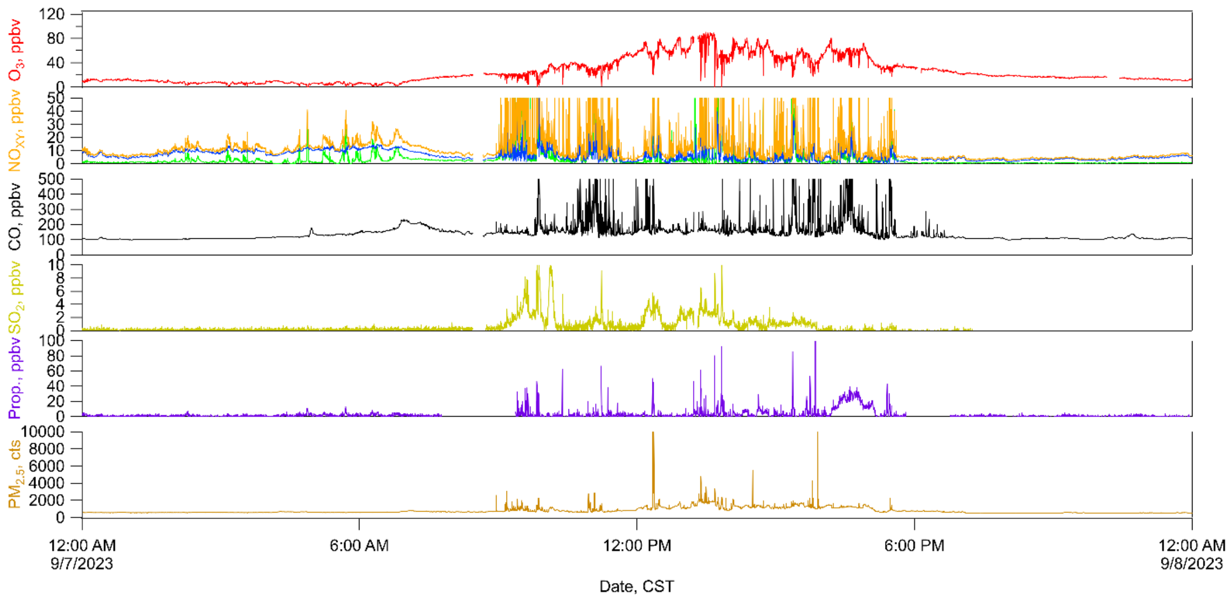

Figure 76. *Time series for selected measurements aboard MAQL3 for September 7, 2024.*

Time	Notes for September 7, 2023
08:43 CST	Switched to HCHO and RAD cal at inlet flowing zero air.
09:30 CST	This morning did the following: PTRMS zero and cals (isoprene + BTEX), swapped out Teflon tubing at the RAD HCHO line at inlet, TG zero and high point, ZA at HCHO and a high point.
09:43 CST	Heading out of La Porte site.
09:44 CST	Stopped at H street due to construction traffic.
	First pass on Grand Parkway
09:47 CST	Starting O_3 around 25ppbv at La Porte.
09:49 CST	Heading east

Time	Notes for September 7, 2023
09:52 CST	On the bridge passing over the ship channel. Traffic emissions, some increase in HCHO.
10:06 CST	Peak in HCHO and propene some VOCs. Near by refineries
10:12 CST	Passing by Mount Bellview seeing high SO_2, HCHO levels.
10:17 CST	CH4 is climbing, now at 2ppm, Hcho dropped but is starting to climb. O_3 mid 30s
10:23 CST	Tanker passed us, saw increase in SO_2, NOx.
10:26 CST	Higher O_3 at the south of old Liberty site, increasing O_3 again 10:43 CST.
10:48 CST	Passed by a mulch facility on the left.
	Second pass back on Grand Parkway
11:08 CST	Exiting at Spring Stuebner to u-turb at Grand Parkway.
11:21 CST	Highly emitting truck in front of us, Jimmy gave us more space between the truck and the mobile lab.
11:44 CST	Seeing low to mid 50s for O_3.
11:54 CST	Seeing slightly lower O_3 in this region, near old liberty site.
11:59 CST	Heading toward Mount Bellview. Big smoky flare at the refinery. CH4 inc. inc in acetone
12:08 CST	Highest O_3 at Mount Belview
12:08 CST	Peaked in O_3, VOCs, just north of I10. Also seeing SO_2
12:15 CST	O_3 dropped with VOCs, but SO_2 is increasing
12:18 CST	Exiting on 1405 to make a U-turn. SO_2 is gradually dropping down.
12:19 CST	Making a U-turn to get back onto
	Third Pass northbound on Grand Parkway
12:20 CST	Behind big smoky truck as we try to get back onto Grand Parkway
12:22 CST	Fell back to clear away from the truck emission
12:27 CST	Seeing a peak in O_3 with VOC
12:30 CST	Seeing up to 90 ppbv of O_3 and HCHO (inc. Of 4 ppbv)
12:37 CST	Passing by fields/crops
	Fourth Pass southbound on Grand Parkway
12:40 CST	Exiting to take another pass through the plume.
12:57 CST	VOC sharp shift down, but seeing SO_2 climbing.
13:01 CST	Exiting onto 1405/Fisher
	Fifth pass northbound on Grand Parkway
13:02 CST	Heading northbound on Grand Parkway.
13:16 CST	GPS was not working
13:16 CST	Heading southbound on Grand Parkway
13:42 CST	Fueling
13:52 CST	Heading out
13:53 CST	Heading onto Grand Parkway Highway.
13:56 CST	Exiting. Making a U-turn onto the Grand Parkway north
14:04 CST	O_3 jumping to 90 ppbv
14:13 CST	Exiting 1413
	Fifth Pass northbound on Grand Parkway

Time	Notes for September 7, 2023
14:14 CST	Stopped at sign and will take a U-turn for Fifth pass northbound
14:15 CST	Heading northbound.
14:20 CST	Seeing some increase in O_3
14:24 CST	Seeing some clouds, lower O_3. Some NOx.
14:26 CST	Passing I10, background levels. Plume is over
	Sixth Pass northbound on Grand Parkway
14:28 CST	Exiting Kilgore Pkwy.
14:29 CST	U turning back onto Grand Parkway
14:35 CST	Passing by refineries seeing increase in low 80s
14:39 CST	O_3 going down so going to U-turn at the next exit.
14:41 CST	Exit 1413 sign
14:42 CST	Exiting 1413.
	Seventh Pass southbound on Grand Parkway.
14:43 CST	Turning U-turn
14:44 CST	Turning around to head back onto the highway
14:49 CST	Increase of O_3.
14:57 CST	Exiting onto Kilgore Pkwy.
	Driving into Belview, driving behind power plants (upwind)
14:57 CST	Turning into the gas station.
15:10 CST	Getting out of Oasis gas station.
15:22 CST	Getting onto I10 Eastbound
15:25 CST	Exiting seeing O3 in the range of mid 60s to 70 at E Wallisville Rd.
15:30 CST	Right turn onto N Main Street northward. Seeing mid to low 60 of O_3.
15:33 CST	Right onto FM 1942,
15:39 CST	Southerly winds per wind sock.
15:42 CST	Stopped at SH146,
15:42 CST	Heading 146 northbound
15:47 CST	Heading towards I 10, traffic emissions, high level of propene.
15:51 CST	Passed propane company saw peak in PTRMS and RAD.
15:53 CST	Big bump
15:54 CST	Left turn onto Grand Parkway Toll Rd.
15:58 CST	Heading northbound on Grand Parkway.
16:02 CST	Mid 50s and 60s in O_3.
16:96 CST	Seeing increases in O_3 more north on the Grand Parkway toll road that earlier. Bay breeze coming through, airport seeing now SE winds.
16:11 CST	High of 90 ppbv of O3 with HCHO
16:13 CST	Exiting Dayton Humble 1960 exit to let train of cars behind us go in front.
16:14 CST	Stopped at an intersection.
16:19 CST	Exiting east toll briefly to get rid of traffic.
16:25 CST	Heavy emitting truck in front.
	Heading back to La Porte
16:34 CST	Exiting I69.

Time	Notes for September 7, 2023
16:35 CST	U-turn onto Grand Parkway Toll Rd. eastbound.
16:54 CST	Seeing increase in O_3 with VOCs and HCHO
17:04 CST	Continual decrease in O_3 after high O_3 period at Liberty
17:24 CST	Ending with mid to high 30s for O_3.
17:31 CST	Taking a left onto Sens Rd.
17:44 CST	Parked inside of La Porte

September 8, 2023

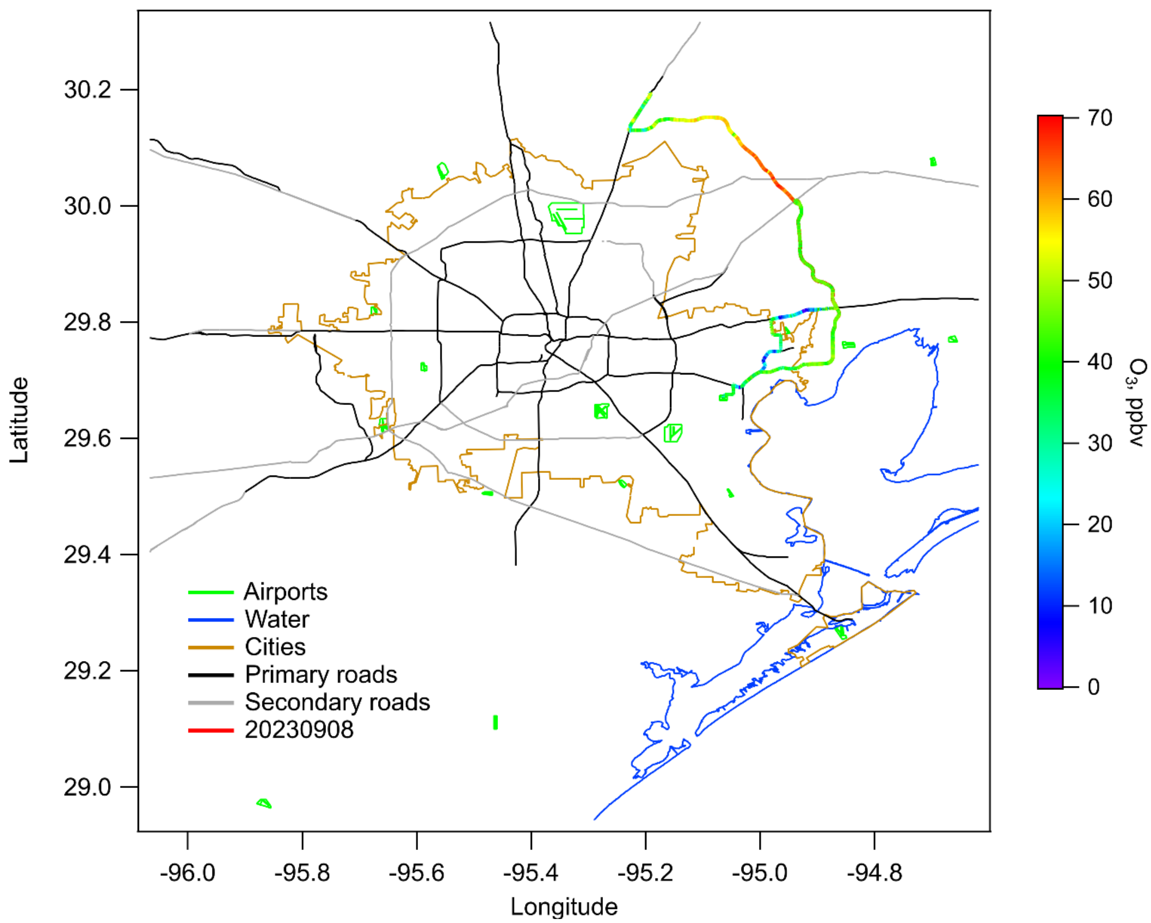

Figure 77. *Spatial plot of mobile measurement of ozone aboard MAQL3 on September 8, 2024.*

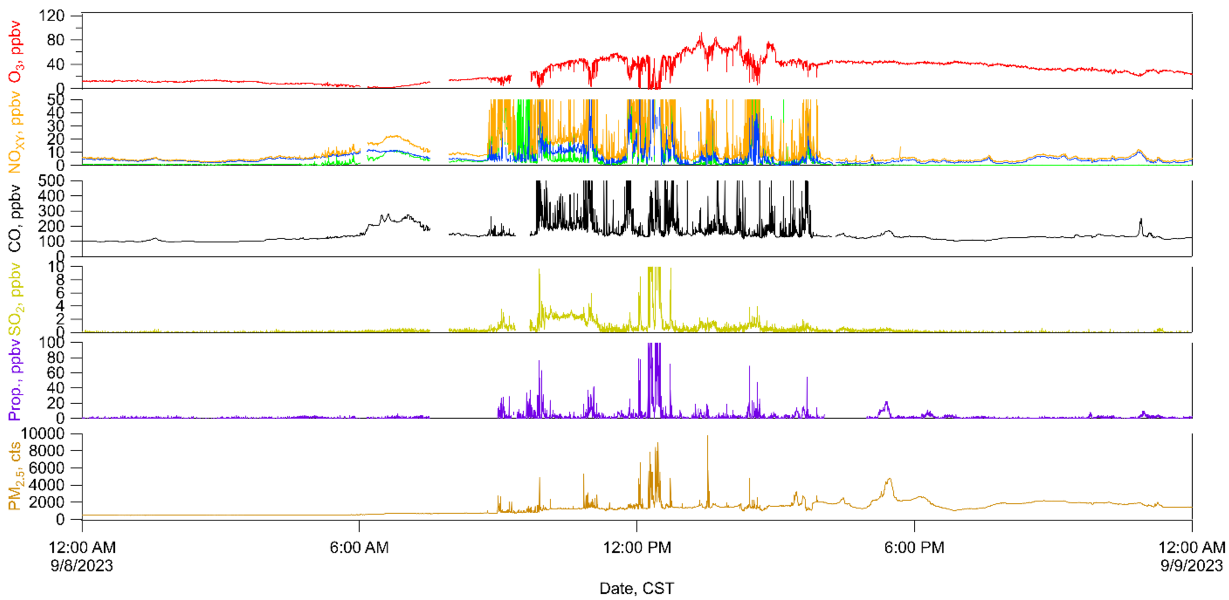

Figure 78. *Time series for selected measurements aboard MAQL3 for September 8, 2024.*

Time	Notes for September 8, 2023
	Heading to Home Depot to grab fans
10:01 CST	On N Main rd.
10:04 CST	On left at Cedar Bayou Lynchburg
10:05 CST	HCHO going up
10:06 CST	Parking into a Lowes store, parked while JHF goes to grab a fan.
10:49 CST	Added a fan to the back to cool instruments.
10:49 CST	Heading out of Lowes, taking right onto Garth Rd.
10:58 CST	On I10 heading west.
11:02 CST	Traffic, slow moving car emissions.
11:06 CST	Heading off of the highway onto service road, very bumpy
	First pass onto Grand Parkway toll.
11:13 CST	Based on airport data, winds are from W/SW
11:19 CST	Slightly increasing O_3 50 ppbv
11:21 CST	Heavily loaded truck cut in. Saw an increase in CO and NOx.
11:22 CST	Coming towards Highway 90
11:28 CST	Heading toward Liberty this spot increasing O_3 into the low 60s
11:32 CST	Exiting Kingwood Drive to let traffic behind us pass.
11:38 CST	O_3 dropping a bit, increased vehicle traffic emissions, not too many cars around
	Heading to gas station
11:46 CST	Exiting to get onto northbound I69 for fuel
11:47 CST	High CO local traffic during interchange
11:53 CST	Stopped in front of traffic before turning left to get to gas station.
11:54 CST	Stopped at US 59 intersection.
11:55 CST	Smells like fuel. Bumpy roads getting in.

Time	Notes for September 8, 2023
	Heading westward of loop to track O3. The sea breeze is coming in
12:33 CST	Heading out to the gas station
12:37 CST	Stopped by service road to turn the engine off and on. Back on the service road to get on the highway.
12:39 CST	Exiting off of I69 to get onto Grand Parkway.
12:42 CST	Stopped at the intersection of Grand Parkway and IH69. Lots of traffic emissions.
12:45 CST	Headed onto Grand Parkway eastward.
12:59 CST	Saw a smaller dip in O_3 passing the Kingswood exit.
13:09 CST	Heading towards Mount Belview plants
13:13 CST	As we head into Mount Belview plants O_3.
13:17 CST	Seeing an increase in O_3 at exit 565.
13:22 CST	Saw O_3 hit 90 ppbv. But seeing big trucks
13:24 CST	Increasing SO_2 plus O_3 up to
13:28 CST	Passing Cedar Port Parkway started dropping in O_3.
13:29 CST	Going westbound and winds are south of the bay. The boat was seeing 50s for O_3.
13:32 CST	Making a U-turn 1405
13:35 CST	Truck in front increasing NOx emissions
13:38 CST	0.5 mile of Kilgore
13:41 CST	Seeing low 90s of O_3, but overall lower O_3 reading due to NOx
13:45 CST	Seeing high levels of CO with little NOx and SO_2, no vehicles around
13:49 CST	Out of O_3 plume, will be turning around.
13:54 CST	Taking an exit to turn around for a bigger O_3 plume.
13:56 CST	Taking a turn back onto South 99/ Grand Parkway toll.
14:00 CST	Going back south
14:07 CST	Seeing a flare
12:11 CST	O_3 going up to 90 slight increase in HCHO and VOCs
14:15 CST	Seeing max peak of O_3 in mid 90s. Heading down to make a turn. Temp dropping, cleaner, drop in temp and increase in RH
14:20 CST	Exiting 1405, stopped at the Oasis gas station
	Heading out of the gas station for
14:13 CST	Heading out of the gas station heading westbound onto 99 Parkway
14:47 CST	Getting sea breeze side of the breeze
14:48 CST	Seeing flare go straight up.
14:49 CST	Seeing an increase in O_3. Baytown airport updated to winds of E (a few min ago it was WSW) water in Picarro dropped.
14:58 CST	Strong winds causing a dust storm out
15:02 CST	Exiting 90, stopped at intersection of US 90. Seeing lower O_3.
15:05 CST	Taking a left onto I90, taking a left onto SH99.
15:14 CST	Very strong winds. Big sand storms, bay town airport seeing 13 mph winds from se. Lowering of O_3
15:24 CST	Entering into some of the storm, at Kilgore Pkwy exit.
15:27 CST	Drove right through a sand storm

Time	Notes for September 8, 2023
15:39 CST	Out of plume. Crossing over the bridge. Not as strong. We are ahead of the storm.
15:42 CST	Exiting off I 45 onto Sens Rd.
15:43 CST	Left onto Sens Rd.
15:48 CST	Stopped by construction on H drive, dust from nearby construction side from La Porte
15:54 CST	Making a turn and self-sampling

September 9, 2023

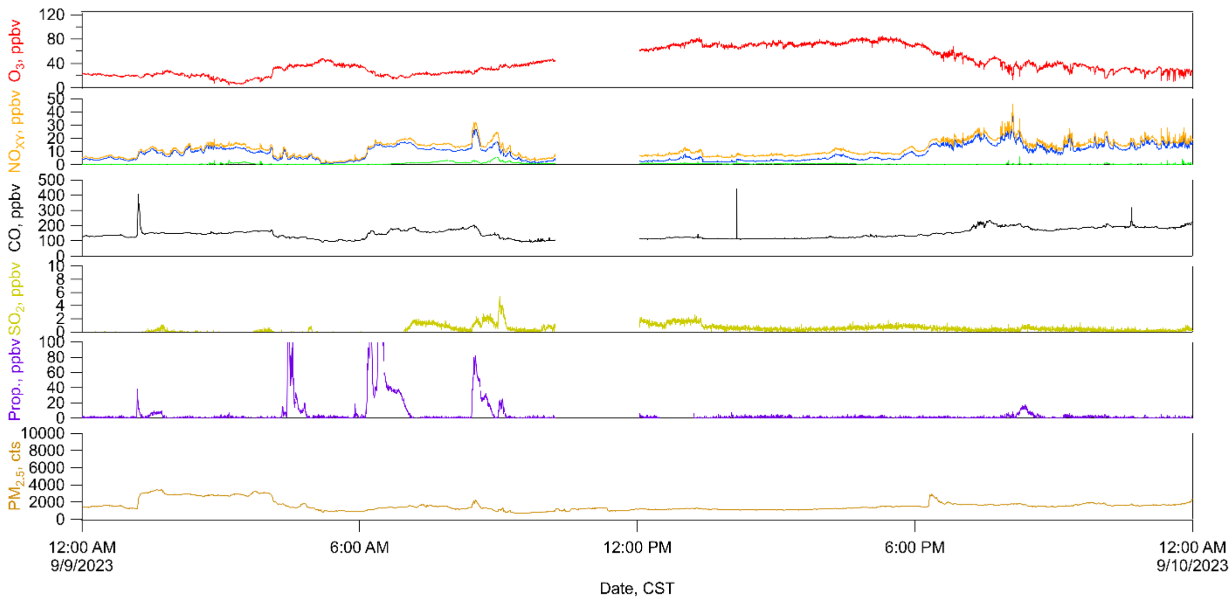

Figure 79. *Time series for selected measurements aboard MAQL3 for September 9, 2024.*

Time	Notes for September 9, 2023
	Down day with Calibration
10:14 CST	starting multiblend calibration TG
10:30 CST	turned HCHO instrument off, working on switching the tubing
11:14 CST	starting zeroing TG line
11:17 CST	starting NO_2 calibration
11:55 CST	switched out solution for hantzch. refilled stripping
12:29 CST	HCHO settling, started running zero via the inlet box. RAD and HCHO cal line on.

September 10, 2023

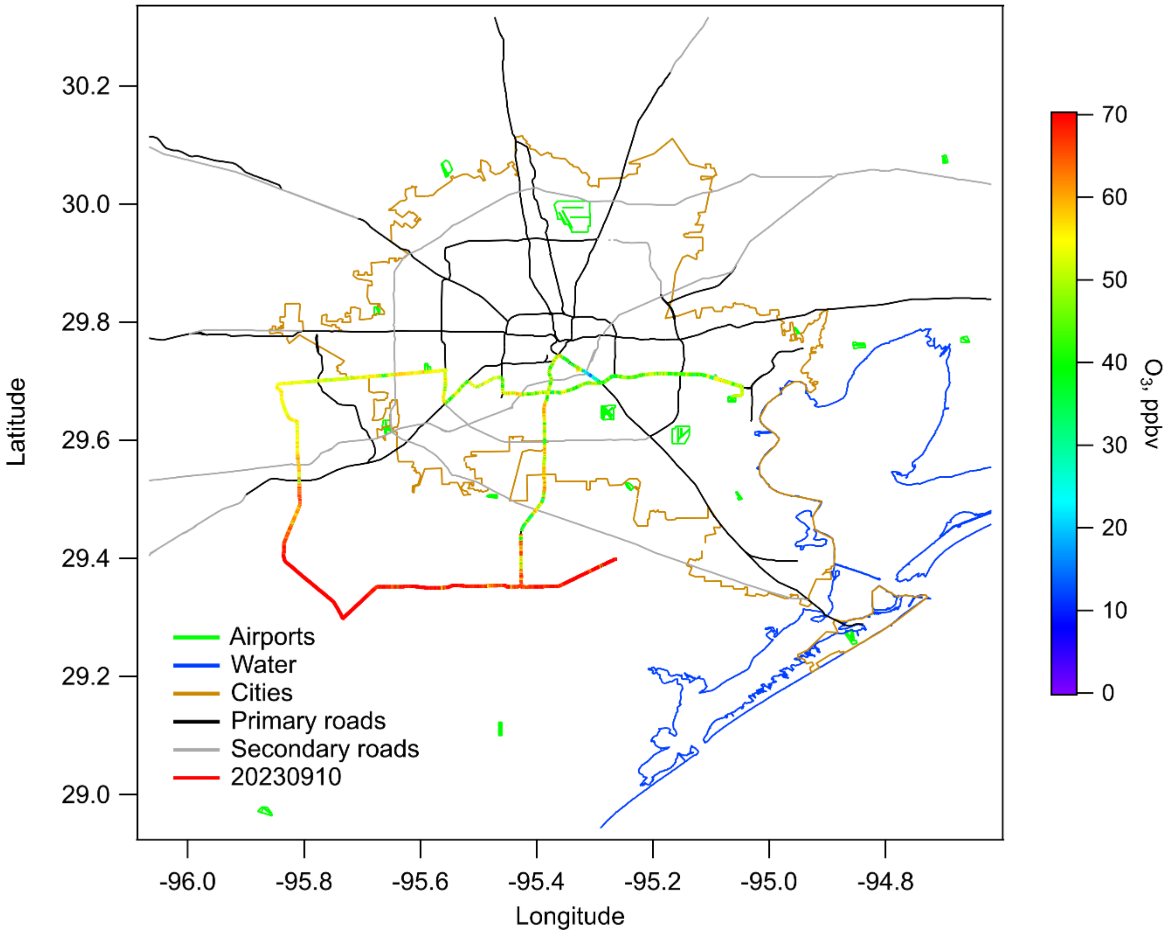

Figure 80. *Spatial plot of mobile measurement of ozone aboard MAQL3 on September 10, 2024.*

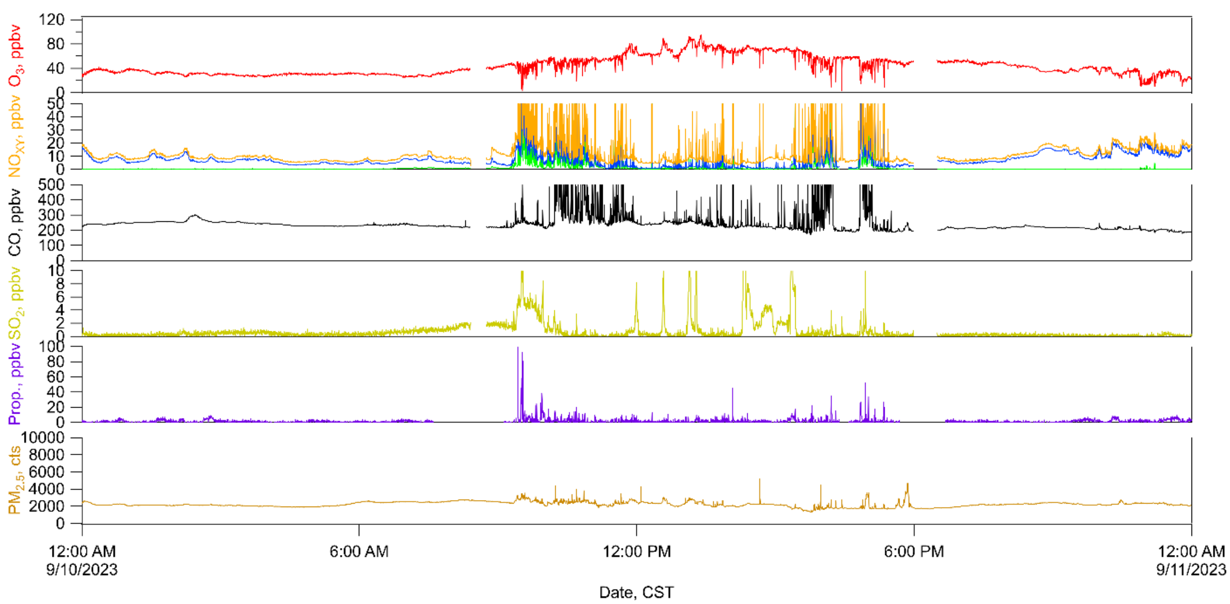

Figure 81. *Time series for selected measurements aboard MAQL3 for September 10, 2024.*

Time	Notes for September 10, 2023
	West Houston Drive. Shifting winds from last few days. Heading to the gas station
08:24 CST	Zeroing TG line and O_3
09:12 CST	At the gate of La Porte.
09:14 CST	Heading out towards H drive. Mid 40s in O_3
09:17 CST	At Sens Rd., taking a left turn on Sens.
09:19 CST	Taking a left onto Independence Highway.
09:25 CST	Exiting onto Independence Rd. To get fuel at Love's gas station.
09:27 CST	Parked and fueling
09:48 CST	Heading out of Love’s.
	Continuing down 225 access road. Toward. Bayland Park.
09:50 CST	Waiting to turn right onto Independence Parkway
09:51 CST	Heading right onto the access road
09:55 CST	Driving by Westlake Epoxy. Smell stuff.
09:56 CST	Passing by PEMEX increasing some in VOCs. Stopped at the traffic light and self sampling. VOCs were increasing. Winds make us downwind of Pemex plant.
10:02 CST	Passing by ITC storage facilities.
10:04 CST	Isobutylene plant heading up marathon pipeline. Stopped at a traffic light.
10:06 CST	Increase in HCHO passing by plastics plant.
10:07 CST	Seeing an increase in hydroxy acetone, HCHO around 7 ppbv as we pass by steam. Increase in CAMFUR (152).
10:10 CST	Driving access road, a section of more residential + commercial.
10:11 CST	Getting back onto the highway. Seeing vehicle emissions.
10:18 CST	Moving westbound on I 610.
10:26 CST	Traffic emissions still. Heading to Bayland Park.
10:29 CST	Exiting onto Bellaire Blvd.
10:30 CST	Taking a right onto Bellaire Blvd.
10:32 CST	Stopped at traffic light Rice Avenue.
10:34 CST	At traffic light still with car emissions.
10:35 CST	At Bissonnet and Chimney Rock
10:47 CST	Low-hanging branches near the area.
10:49 CST	Opened and closed ceilometer.
	First Arc - Southwest of Houston
10:51 CST	Heading towards Fulshear city, going to take Westpark tollway, westbound.
10:58 CST	Exiting to get on the tollway.
10:59 CST	Less cars on toll.
11:01 CST	Seeing high 50s and low 60s in O_3, slight increase as we head to Alief.
11:10 CST	Likely north of the plume, seeing slightly lower O_3 (low to mid 50s)
11:17 CST	Seeing 60 ppbv of O_3.
	Starting the transect of the arc.
11:17 CST	Taking a left onto FM 359 South Rd.
11:22 CST	Sugar Land airport seeing 10mph NE winds.
11:30 CST	Heading into Richmond, seeing high 50s low 60s O_3.

Time	Notes for September 10, 2023
11:33 CST	Stuck in local rad traffic. But seeing low 60s in the O_3.
11:38 CST	Moving out of the local traffic.
11:47 CST	Seeing mid to high 60s, general increase. Heading northbound.
11:48 CST	Low 70s
11:50 CST	Seeing higher O_3 (80ppbv, with inc in HCHO) with increasing SO_2.
11:52 CST	Needville approaching.
11:54 CST	Drop in O_3, HCHO, SO_2,
11:57 CST	Noticed a smoky tractor.
11:58 CST	SO_2 increased up to 5 ppbv with an increase in O_3 and HCH.
11:59 CST	SO_2 increase, 12 ppbv.
12:01 CST	Gradual inc in methane while SO_2 and O_3 decreased.
12:03 CST	Out of plume, low SO_2
12:04 CST	Turning gas station
	Heading back, eastbound.
12:32 CST	Out from gas station, O_3 is in mid 70s and increasing and SO_2 is also increasing.
12:32 CST	About 10 ppbv of SO_2. Seeing low 90 ppbv of O_3. In the parish plume.
12:48 CST	Seeing low 60s and low SO_2, out of plume.
12:49 CST	Before Richmond and Rosenberg
	Third pass westbound
12:50 CST	Turning around a Valero gas station. To go back southbound.
12>59 CST	Heading towards mid 70s
13:04 CST	Mid to higher 70s of O_2. SO_2 is increasing.
13:06 CST	Mid 80s in O_3, increased SO_2. Highway 36 and FM 1994.
13:08 CST	SO_2 highest so far at 15 ppbv. HCHO is 7.1 ppbv.
	Eastbound.
13:12 CST	Turned left onto taking eastbound
13:14 CST	SO_2 is increasing. SO_2 high around 13:17 seeing 21 ppbv SO_2.
13:12 CST	Mid 90s in O_3, low NOx but some NOy. Coming out of plume.
13:45 CST	Seeing some increase in
13:46 CST	Driving into Alvin Lutheran church to make a U-turn.
	Westbound on
13:49 CST	Starting back on to FM 1462
13:57 CST	Seeing a dust storm in front. Will hit in a few seconds. Neph saw a sharp peak, but nothing in POPS or taps.
14:00 CST	Dropping in O_3, stopped at a traffic light.
14:07 CST	Slightly increasing O_3, and SO_2.
14:16 CST	Seeing some increase in SO_2. Higher SO_2 , but not as much O_3 like previously,
14:23 CST	Came into the parking lot. Seeing an increase in SO_2 and with some increase to O_3. Winds are N, NE
	Heading back to ERP to change O_2 tank.
15:12 CST	Heading out of the gas station to go to ERP. Sat during an SO_2 plume near Parish plume.

Time	Notes for September 10, 2023
15:20 CST	Sharp peak in SO_2, 17 ppbv.
15:22 CST	Stopping by a gas station to check on the transmission light on the truck.
15:23 CST	Cleared the sign and now heading out of gas station.
15:25 CST	Stopped at intersection
15:39 CST	Stopped at SH288 intersection. Taking a left to go northbound.
15:46 CST	No trucks, high CO emissions, likely personal smaller cars.
16:04 CST	3 ppm of CO
16:05 CST	Camero and Charger cars racing on the highway saw up to 10 ppm of CO.
16:09 CST	Heading onto I 45 south. Towards ERP, measuring a lot of gasoline emissions.
16:11 CST	Exiting off of Cullen Blvd.
16:14 CST	Driving into ERP.
16:46 CST	Finishing up at ERP, changed O_2 tank
	Heading to gas station to fuel up then to La Porte
16:47 CST	Heading out of ERP
16:56 CST	Seeing smoke up ahead, likely from a flare
17:08 CST	Driving into Love's gas station.
17:10 CST	Parked for gas.
17:19 CST	Heading out to La Porte Site.
17:27 CST	Stopping at the intersection to take a right onto Sens Rd.
17:29 CST	Taking a right onto North H Street
17:35 CST	Parking into place at La Porte.
	In the evening during TG zero noticed that the SO_2 was not very clean

September 11, 2023

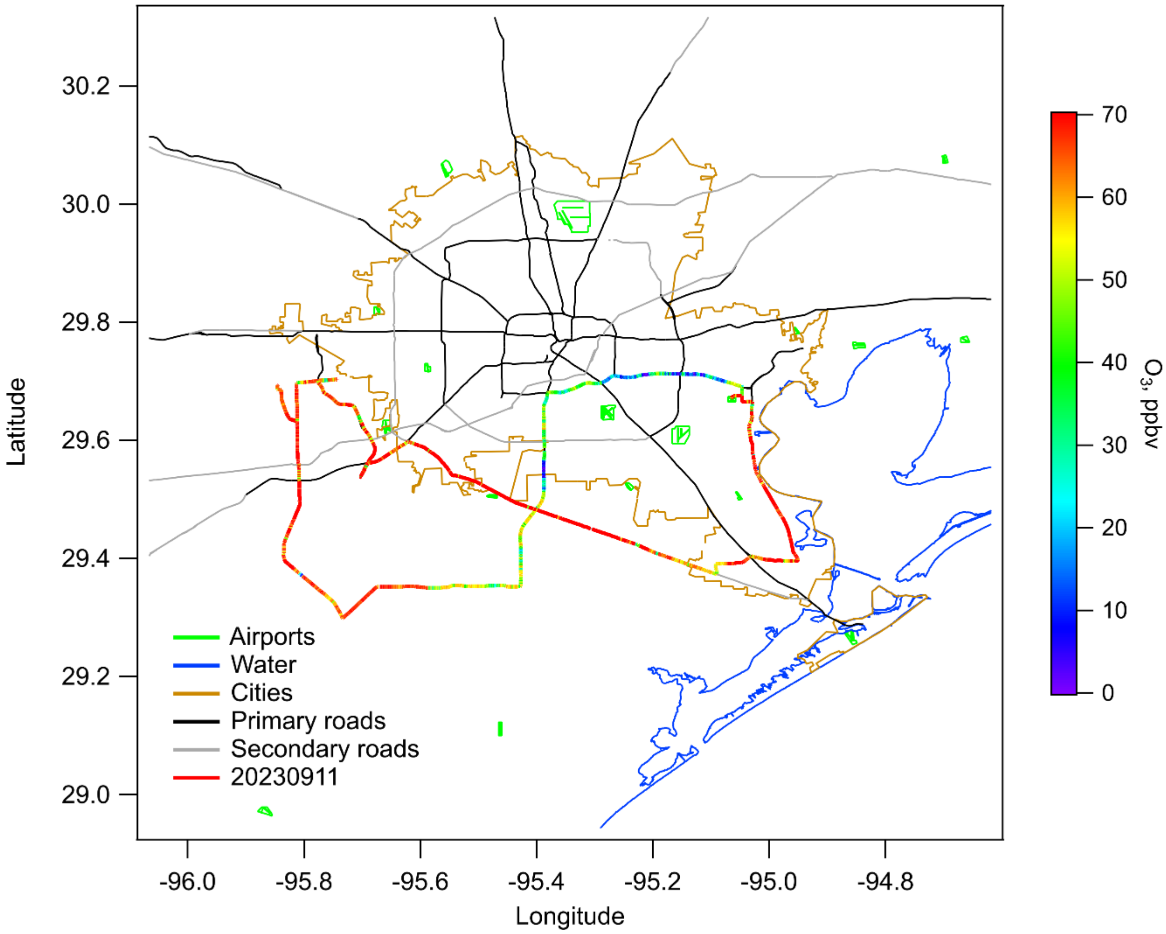

Figure 82. *Spatial plot of mobile measurement of ozone aboard MAQL3 on September 11, 2024.*

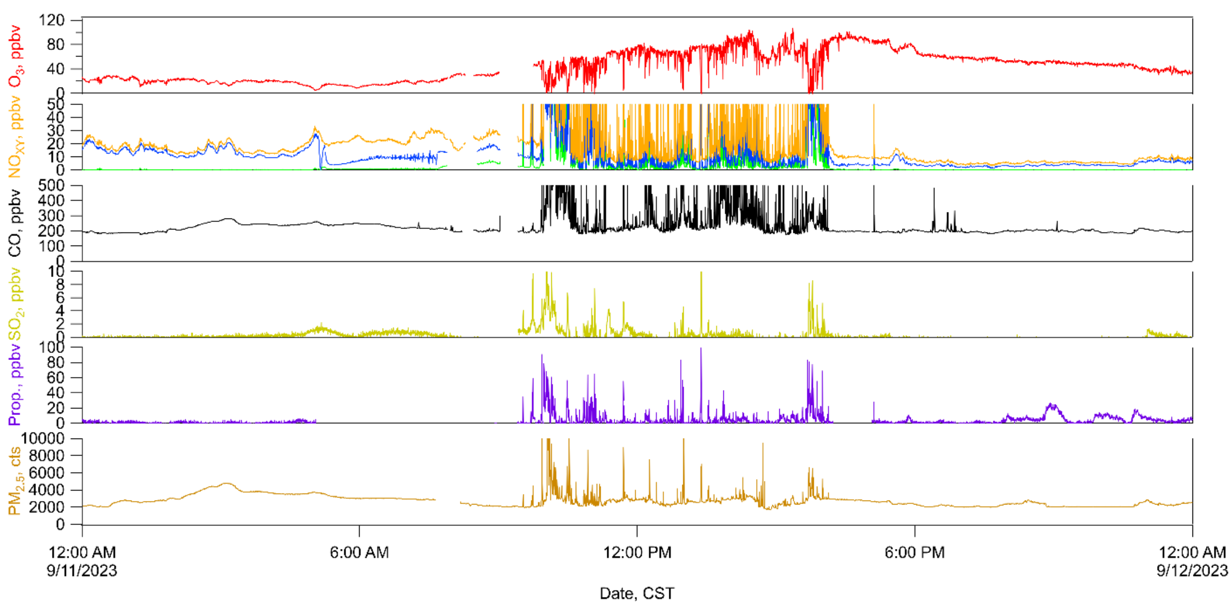

Figure 83. *Time series for selected measurements aboard MAQL3 for September 11, 2024.*

Time	Notes for September 11, 2023
08:50 CST	HCHO zero
09:48 CST	Issue with Garmin, keeping a close eye on Airmar
09:50 CST	Heading out of La Porte
10:03 CST	High concentrations of NOxy and SO_2 with increase in VOCs and HCHO
10:04 CST	Particle rate increase in the pops.
10:16 CST	Smell of smoky tire, the trailer had burned tire.
10:18 CST	Galveston O_3 in the 70s now.
10:19 CST	Smoke or dust on the other side of the highway.
10:29 CST	Big dump trucks passing in front, 200+ of NO_{XY}. With pops increase. SO_2
10:32 CST	Bobtail rig in front with 100 ppbv of NOx with aerosol
10:35 CST	Very rough road on the highway. Will stop by a gas station to check on the connection.
10:45 CST	Taking a left into a gas station to check on instruments.
10:46 CST	Stopped
11:05 CST	Leaving gas station
11:07 CST	Leaving gas station back on
11:17 CST	Behind a dump truck small road.
11:21 CST	Briefly stopped by the side to let vehicles pass. Lower NOx. Seeing higher 60s in O_3. With increasing SO_2.
11:24 CST	Catching up to traffic and truck.
11:28 CST	Increasing O_3 with traffic cleared in front, seeing some increase in particle number count. SO_2 was also elevated.
11:31 CST	Stable O_3 level, high 60s, low 70s, slow decline in SO_2, very little NOx.
11:33 CST	At the intersection of
11:34 CST	Behind a dump truck.... After clearing it from behind seeing about same O_3 levels.
11:37 CST	High 60s/low 70s for O_3.
11:41 CST	Slow moving traffic at the intersection.
11:42 CST	Dump truck in front of us. Seeing NOx in the 200 ppbv.
11:42 CST	Stopped at traffic briefly got plume from truck in front.
11:47 CST	Increasing O_3, around mid 70s with increasing SO_2.
11:48 CST	Stopped at an intersection near Family Dollar and Shell.
12:02 CST	Stopped by gas station
12:04 CST	Heading out of gas station.
12;07 CST	Low 80s as we approach highway 59.
12:10 CST	Going under bridge.
12:11 CST	Seeing HCHO lower.
12:14 CST	A lot of traffic not seeing much O_3 today.
12:17 CST	Clearing NOx, seeing mid 70s. Heading north of town.
12:20 CST	HCHO is lower as we see O_3 lowering
12:24 CST	Getting close to Fulshear Town, seeing low 70s
12:29 CST	Seeing low 60s and dropping HCHO. Making U-turn to go south
	Heading south on FM 359 to then get us on the 99 (Grand Parkway Toll Road)

Time	Notes for September 11, 2023
12:31 CST	Turning into Parkway Fellowship church to make a U-turn to go back. HCHO is down.
12:33 CST	Heading back south on FM 359
12:38 CST	Seeing an increase in O_3, towards 70.
12:40 CST	At the stop sign to take a left onto FM 723.
12:44 CST	As we head north on FM 723 seeing a light increase in O_3 and HCHO.
12:51 CST	Exiting FM1093
12:56 CST	Stopped at the traffic light to go back to Grand Parkway (99). Vehicle acceleration seeing high HCHO.
12:59 CST	At traffic light of SH99 and FM 1093.
13:00 CST	Heading onto FM 99.
13:04 CST	Cleared of NOx.
13:09 CST	Increase in O_3. Close to 80 but hit by truck plume
13:12 CST	Drove on very fresh asphalt and it smells
13:14 CST	U-turn to drive into a HEB parking lot to check on Lidar
13:27 CST	Starting to travel out of HEB. Fixed lidar. O_3 is mid to high 70s
13:30 CST	Heading out on Highway 69. Hit by traffic with increasing particle number.
13:38 CST	Heading back onto the Crab River rd. northbound.
13:42 CST	Message that on 20th -21st Doug and Sushil are visiting.
13:43 CST	Heading onto US 59.
13.44 CST	Heading over to Sugar Land area.
13:51 CST	Mid 80s for Ox, increasing HCHO, ceilometer is working.
13:56 CST	Seeing closer to high 80s in the Ox
13:57 CST	Stopped at intersection where we saw O_3 go up to mid to low 90s
14:07 CST	Missouri city passing fort bend highway. Seeing low to mid 90s and HCHO around 5 ppbv.
14:15 CST	Mid 90s for O_3.
14:22 CST	Hit 100 ppbv of O_3.
14:23 CST	Seeing dusty on other side of street.
14:26 CST	Seeing 105 ppbv in O_3 in Manvel
14:30 CST	Dusty streets.
14:33 CST	In Alvin, O_3 dropped to mid 80s. Now
14:42 CST	Seeing bay breeze, with cleaner air and also increase in H2O.
14:45 CST	Driving through the school district.
14:48 CST	Taking a left onto FM 646 heading north towards La Porte
14:56 CST	Seeing O_3 going up to mid low 70s. Seeing similar trends with Picarro. Small inc in acetaldehyde.
14:59 CST	Heading onto highway
	Interface of marine and continental boundary layers.
15:02 CST	Heading north on highway and seeing increase in O_3. In the low 80s.
15:05 CST	Heading into traffic.
15:07 CST	Seeing high low 80s for O3 and increasing. To mid 80s.
15:09 CST	Right onto SH 146
15:12 CST	90 ppbv of O_3 with a peak in HCHO.

Time	Notes for September 11, 2023
15:14 CST	High 80s in O_3, variability in H2O and can see variability in O_3 and HCHO
15:15 CST	Stopped at the traffic light.
15:21 CST	O_3 reached 109 ppbv of O_3, HCHO also increased.
15:24 CST	Heading towards traffic.
15:25 CST	Construction work is being done on the left hand side
15:28 CST	Seeing close to high 60s/low70s as we pass Kemah, same levels that boat was seeing.
15:38 CST	Smells emissions.
15:38 CST	Stopping for gas. Exiting 288.
15:40 CST	Still seeing high O_3.
15:55 CST	Heading out from the gas station.
15:56 CST	Heading back onto the highway. Big bump on the road.
15:59 CST	Exiting Spencer Hwy. Left on to Spencer
16:03 CST	Still seeing high O_3, close to 89 ppbv. Close to the La Porte site.
16:05 CST	Taking a left on H street.
16:07 CST	Taking a turn into Buchanan
16:13 CST	Parked at La Porte

September 12, 2023

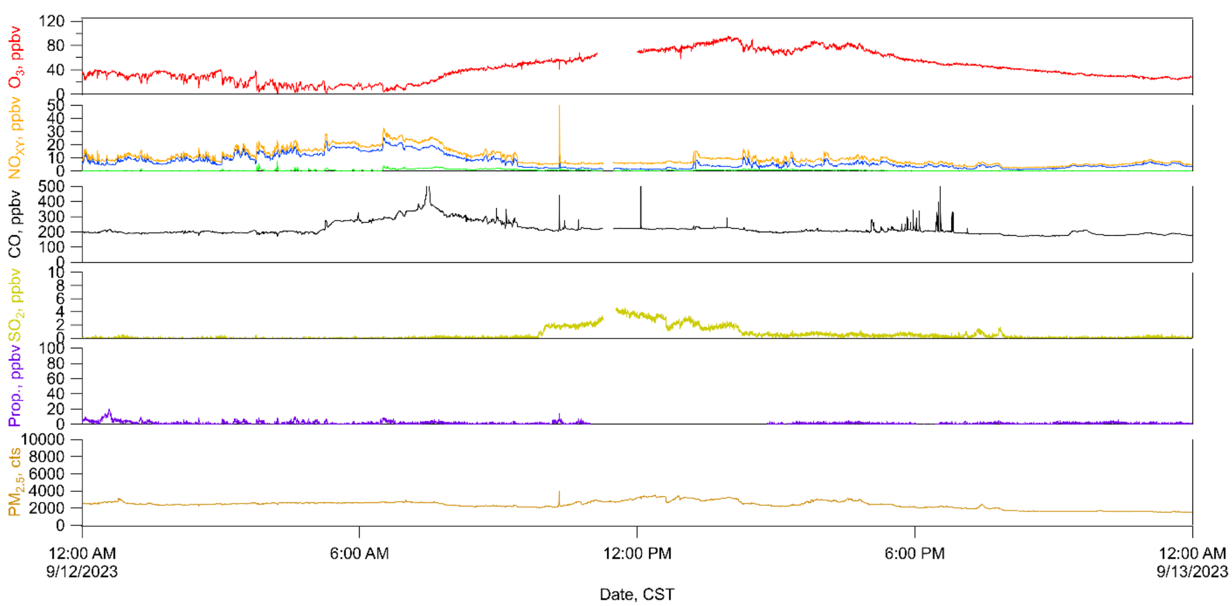

Figure 84. *Time series for selected measurements aboard MAQL3 for September 12, 2024.*

September 13, 2023

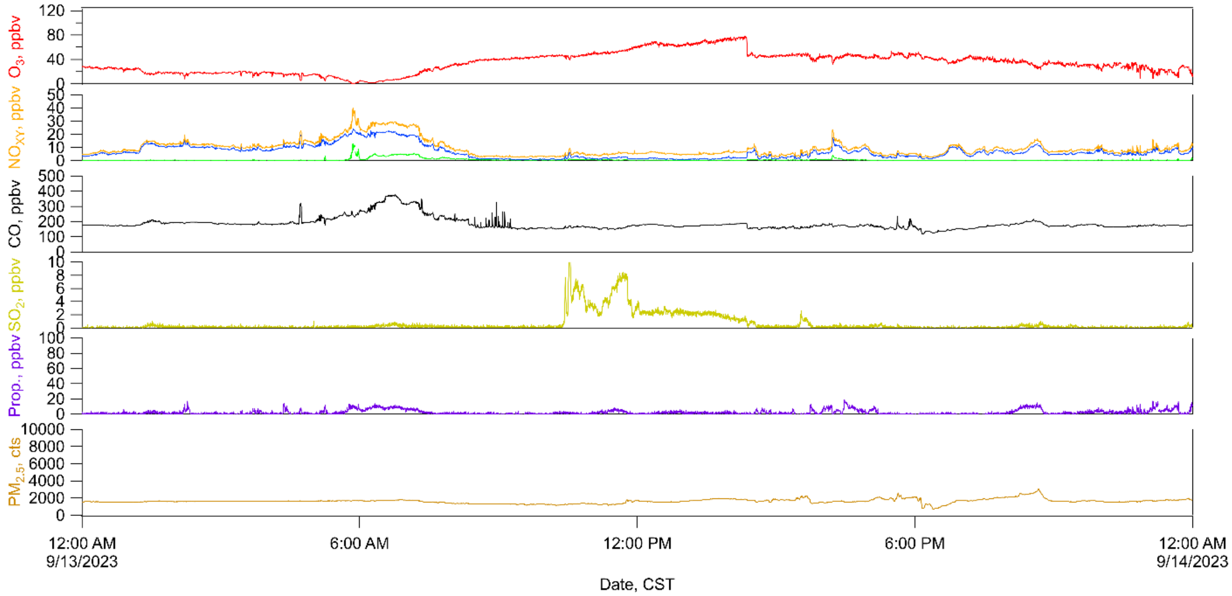

Figure 85. *Time series for selected measurements aboard MAQL3 for September 13, 2024.*

September 14, 2023

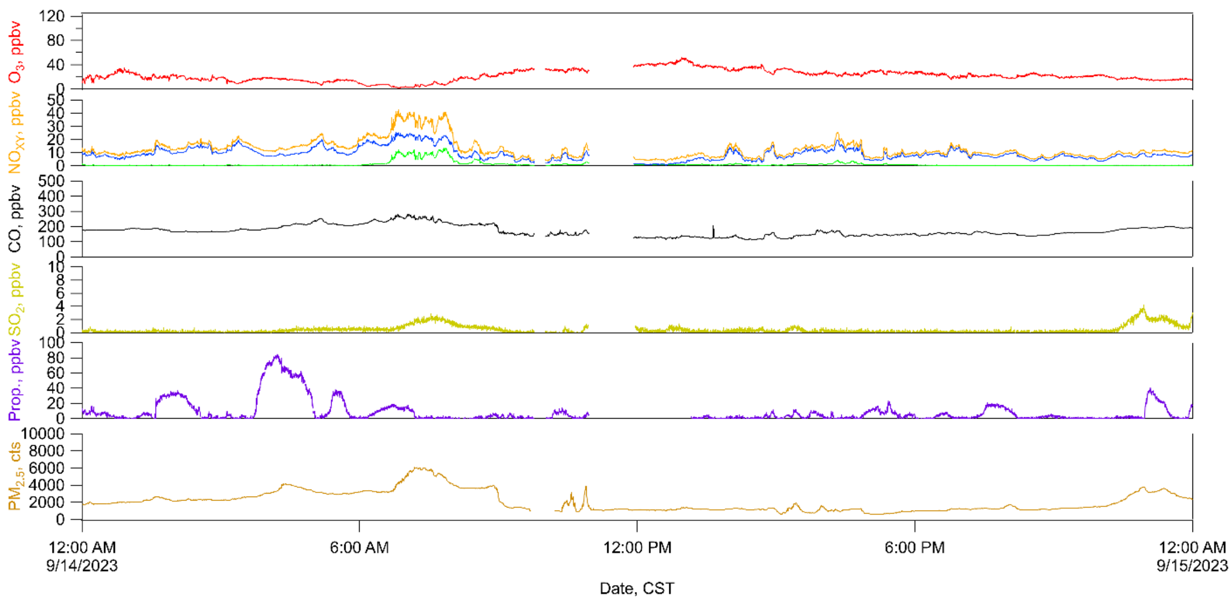

Figure 86. *Time series for selected measurements aboard MAQL3 for September 14, 2024*

September 15, 2023

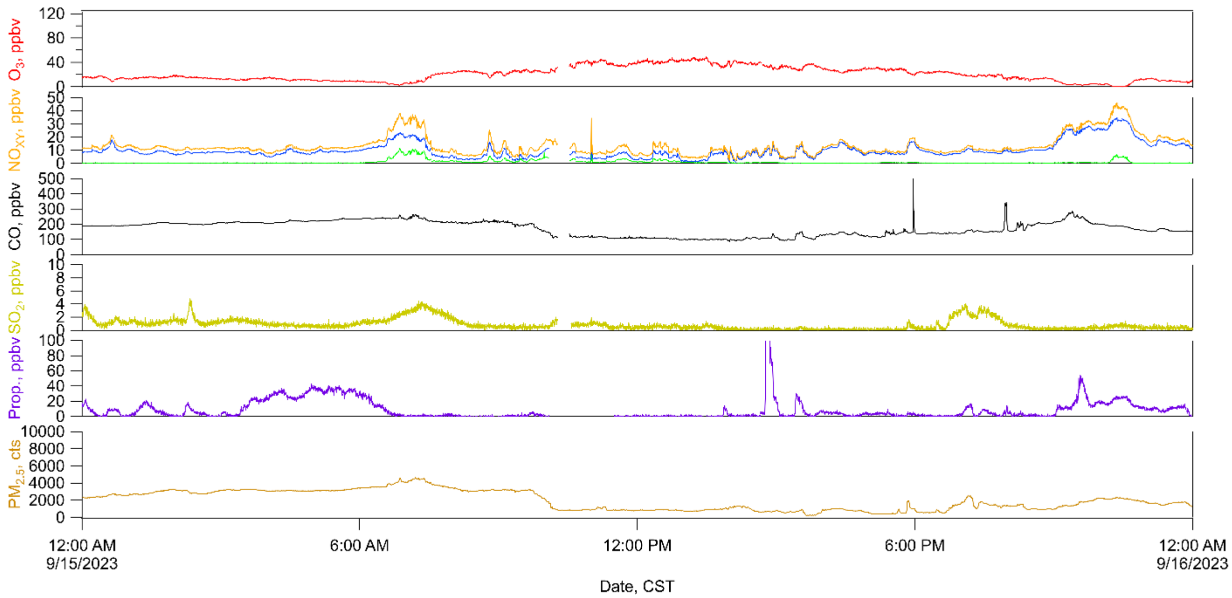

__Figure 87.__ Time series for selected measurements aboard MAQL3 for September 15, 2024

September 16, 2023

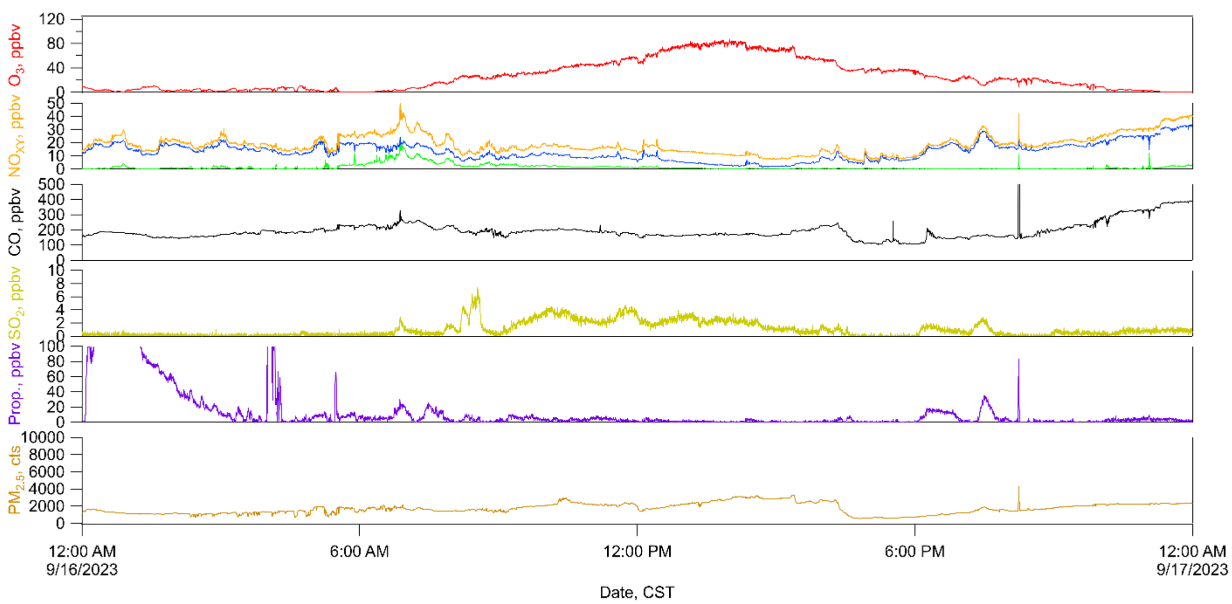

__Figure 88.__ Time series for selected measurements aboard MAQL3 for September 16, 2024

September 17, 2023

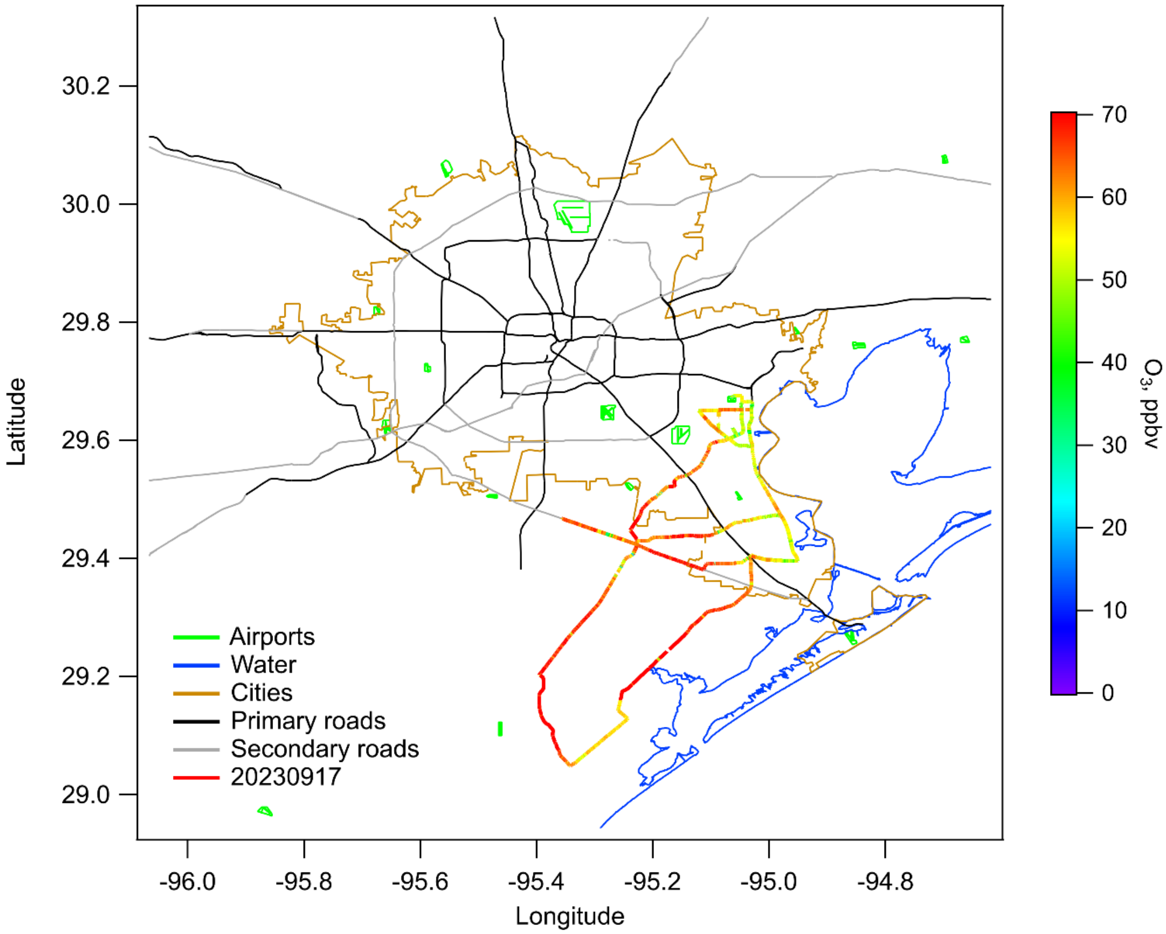

Figure 89. *Spatial plot of mobile measurement of ozone aboard MAQL3 on September 17, 2024.*

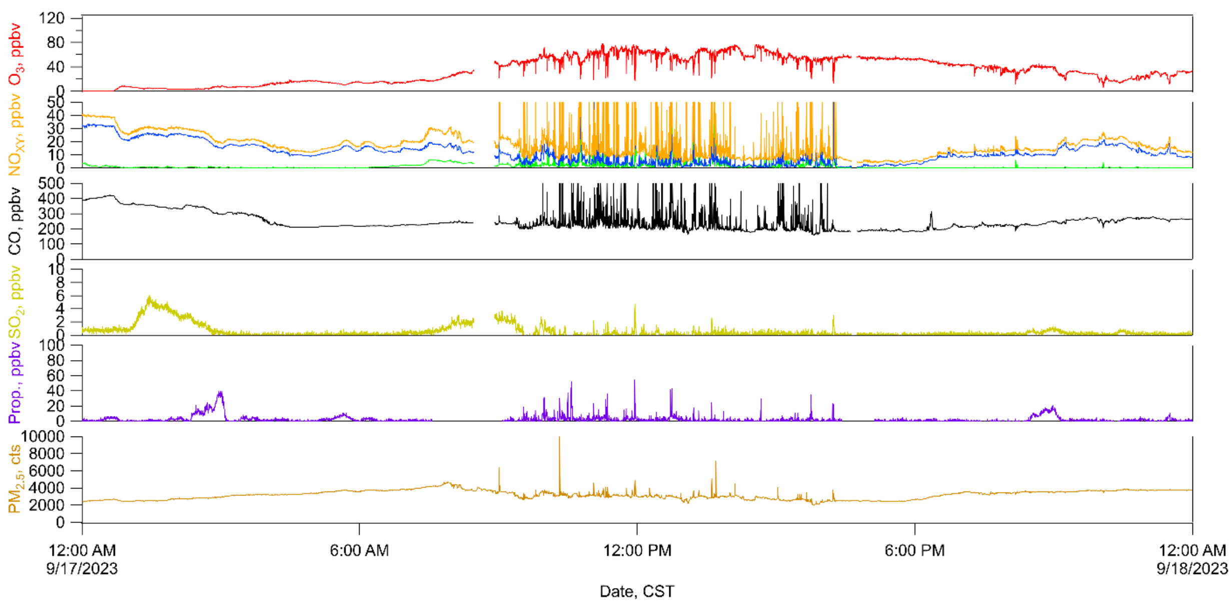

Figure 90. *Time series for selected measurements aboard MAQL3 for September 17, 2024*

Time	Notes for September 17, 2023
09:02 CST	Finished morning zeros and span
09:16 CST	Heading out for driving.
09:22 CST	Heading out on Sens rd.
	First drive south.
09:26 CST	Heading south starting our loop
09:27 CST	Smells, seeing O_3 in the high 40s, not much in the VOCs.
09:30 CST	Seeing a decrease in so_2 and HCHO when we started south
09:33 CST	Stopped at Bayport Blvd. Waiting to take right.
09:34 CST	Seeing an increase in VOCs as we come down Bayport Blvd.
09:35 CST	Seeing an increase in HCHO and propene. In front of Linde and other chemical companies, headed to a dead end.
09:39 CST	Taking a left at Bay Area Blvd.
09:42 CST	Taking a left onto Red Bluff Rd.
09:45 CST	Taking right onto Underwood Drive. Driving within chemical companies.
09:48 CST	Three-point turn.
09:50 CST	Heading back onto Red Bluff Blvd.
09:52 CST	Increasing O_3 and HCHO more drastically than before.
09:56 CST	Passing by a rodeo on the right. Downwind. Seeing 13 ppbv HCHO and gradual increase in NOx.
09:57 CST	Taking a right onto Fairmont Pkwy. Parallel to rodeo and saw a decrease in NOx. Still seeing an increase in propene and HCHO (20 ppbv)
10:00 CST	Gradual dropped down in HCHO and propene as we are upwind of the rodeo.
10:03 CST	Taking a left onto Underwood Rd.
10:04 CST	Big bump
10:05 CST	Taking a turn around to head back eastward.
10:07 CST	Stopped at Fairmont Pkwy. Will take a right heading eastbound.
	The second pass at Bayport
10:12 CST	Taking south on Bay Area Blvd.
10:15 CST	Upwind side. Mid 50s for O_3 with a drop in HCHO.
10:16 CST	Tetramethalbenzene peak as we pass Air Liquide.
10:22 CST	Heading right onto Red Bluff Rd. North westbound.
10:25 CST	Seeing low 60s in the O_3.
10:30 CST	HCHO is increasing at 2023 Pasadena Rodeo, not seeing as much O_3 and HCHO during this loop.
10:31 CST	Taking a left onto Fairmont eastbound.
10:34 CST	Seeing traffic emission with an increase in HCHO.
	Heading down to Alvin.
10:41 CST	Stopped at Bay Area Blvd. Continuing on to go towards Alvin.
10:43 CST	Taking a right onto SH146 heading south in traffic
10:46 CST	Spike in benzene and CH4... Passing by some refineries.
10:48 CST	Exited SH 146
10:53 CST	Taking a left onto Bay Area Blvd. Southwest.
10:56 CST	Seeing an increase in O_3.
11:06 CST	Seeing an increase in local traffic on this segment of Bay Area Blvd.

Time	Notes for September 17, 2023
11:10 CST	Passing under I 45. Quite a bit of traffic.
11:13 CST	Saw O3 get to mid 70s with several ppbv of NOx, residential area.
11:14 CST	Right onto FM528. We should be on the upwind side of the road.
11:17 CST	Saw a big decrease in O_2 and HCHO after passing Parkwood and Parkwood Village Dr.
11:23 CST	Mid 60s at Whitaker Drive. Less traffic and less commercial/residential buildings.
11:26 CST	Seeing a slow increase in O3 and HCHO
11:30 CST	Stopped at SH 35, stopped for a few mins, heading southeast.
11:38 CST	Exited off
11:48 CST	Heading back passing by Chevron lubricant distributor near Alvin. Increase in CH4 VOCs and CO.
11:44 CST	Taking a left onto SH6. Driving into a subway for lunch and bathroom.
12:01 CST	Heading out of the shopping mall.
	Gradual dec in O_3 and HCHO as we move westward. Seeing gradual increases in O_3
12:15 CST	Heading into the gas station to turn around
	Southwest bound on Hwy 6 - heading to Dickinson
12:16 CST	At the intersection of SH6 and FM1128. Left onto IH6
12:27 CST	Downwind lots of traffic.
12:36 CST	Increasing O_3, but got into some NOx emission.
12:41 CST	Stopped at a traffic light
12:45 CST	Stopped in front of I45 and FM517 getting hit with a lot of traffic emissions.
12:49 CST	Heading toward highway
	West bound on FM1764
13:10 CST	Heading towards UH Coastal Center.
13:17 CST	Heading toward Hwy 6.
13:22 CST	Right onto Highway 6.
13:33 CST	Heading towards SH35 intersection.
13:34 CST	Heading southbound onto SH35
13:39 CST	A motorcycle passed by us and is in front.
14:00 CST	Getting into low to mid 70s for O_3. As we head east bound towards coast.
14:05 CST	Drop in HCHO and O_3 slightly.
14:07 CST	Increasing O_3 and HCHO, deciding to continue.
14:11 CST	Motor cyclists drove pass us.
14:16 CST	Made a left turn into
14:18 CST	Know when to turn seeing a decrease in O_3, NOx and S
14:24 CST	Do NOT try this road... Too narrow.
14:28 CST	Taking a left turn onto the narrow road.
14:33 CST	O_3 jumped up to mid 70s taking a right onto 2004 and going north
14:36 CST	Seeing INEOS passing by closer to 14:39. Seeing O_3 in the low to mid 70s.
14:39 CST	Smelly by passing INEOS
14:55 CST	Low 60s in O_3.
14:56 CST	Smells like meat cooking.

Time	Notes for September 17, 2023
14:58 CST	Coastal center passing by seeing low 60s
15:00 CST	Taking a left onto small road FM 2004. Seeing high 60s
15:08 CST	Getting onto the service road on Emmit Lowery Freeway.
15:15 CST	Passing by Dickinson's Bay.
15:38 CST	Smells like nail polish remover, refineries on the left and trains right. Seeing some VOCs.
15:42 CST	Pulling into a gas station
15:55 CST	Heading out of the gas station to the north
15:58 CST	Big bump on our way back to the highway.
15:59 CST	Exiting the highway getting onto the main street
16:05 CST	Turning into H drive.
16:07 CST	Cable dropped onto our inlet.
16:15 CST	Entering into La Porte
16:18 CST	Backing into a parking spot.

September 18, 2023

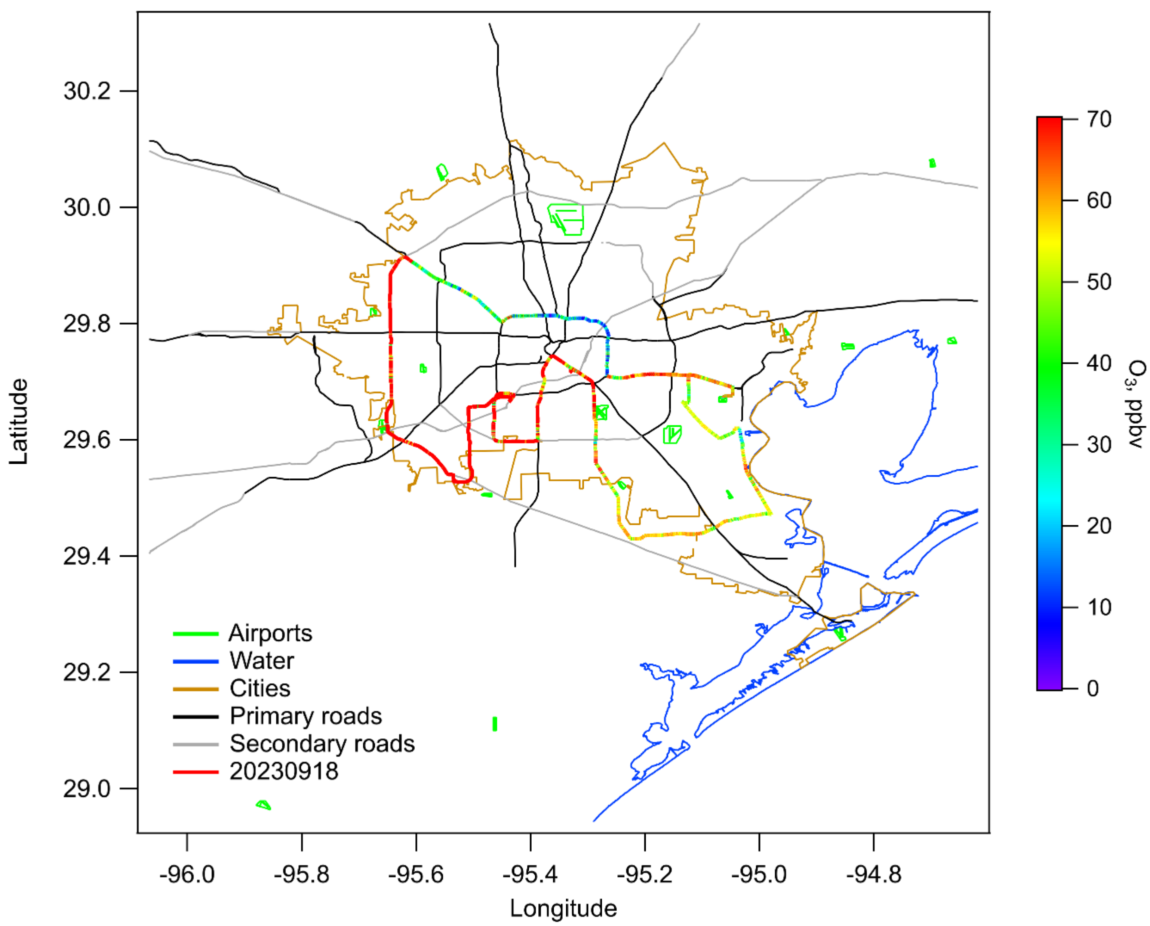

Figure 91. *Spatial plot of mobile measurement of ozone aboard MAQL3 on September 18, 2024.*

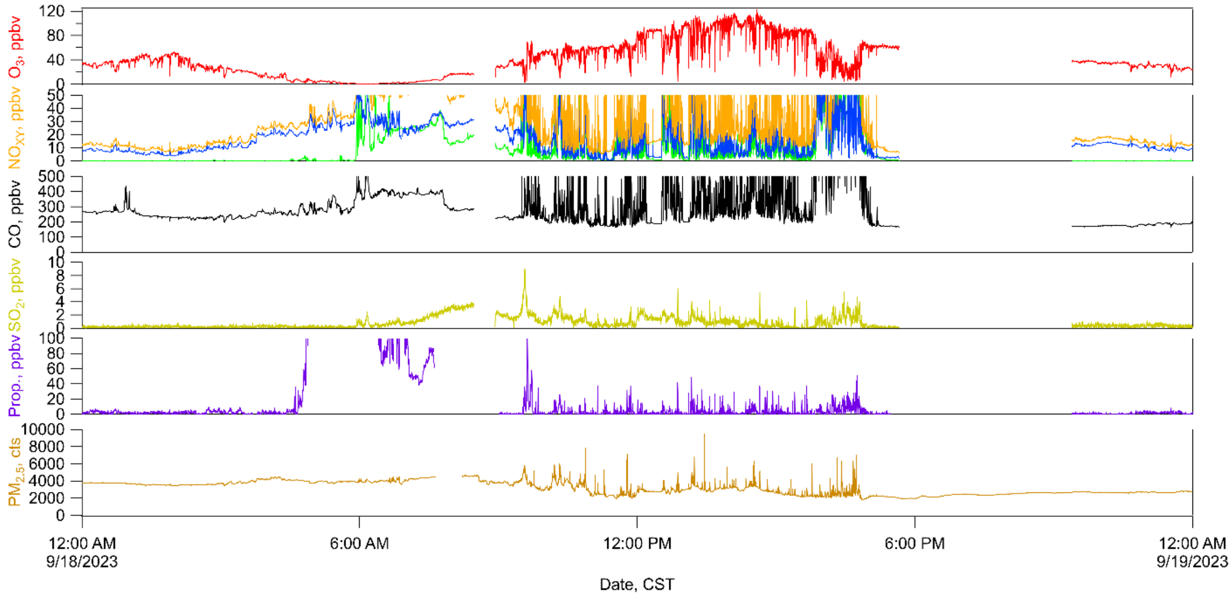

Figure 92. *Time series for selected measurements aboard MAQL3 for September 18, 2024*

Time	Notes for September 18, 2023
09:02 CST	Zeroed HCHO (looks good), zero, and spanned TG line
09:04 CST	Noticed elevated TG when arrived at the site.
09:18 CST	Heading out of La Porte
09:29 CST	Driving slow on H Street to watch out for telecom lines
09:32 CST	Do manual auto zeros for RAD
09:33 CST	Heading onto the highway. Seeing elevated NOx and SO_2.
09:36 CST	Exiting Tidal Rd. Seeing big peak in HCHO and rising.
09:38 CST	Consistent HCHO levels around 21 ppbv on tidal rd. Service rd.
09:41 CST	Going over railroad, slow. On the road heading south on Center St. Commercial properties. Light to mid traffic.
09:50 CST	Pretty bumpy roads. Seeing Ox around low 50s
09:52 CST	Taking a left onto Red Bluff Rd. Heading northwest
09:53 CST	Driving into a Kroger parking lot to readjust GPS. Parked in front of Wells Fargo, not self-sampling seeing low 50s of O_3.
09:56 CST	Heading back on Red Bluff to go southeast
10:08 CST	Heading down Red Bluff Rd. Southwest seeing light traffic not much businesses some industrial nonresidential. Seeing a gradual increase in NOx and SO_2.
10:10 CST	Taking a left onto Bay Area Blvd. Heading northeast.
10:12 CST	Pops aerosol seeing a gradual increase on this road. And increase in SO_2. Increase in benzene. Catching cross winds from facilities nearby (southeast)
10:14 CST	A gradual decline of SO_2 after passing the facility.
10:15 CST	Taking a left (eastbound)
10:16 CST	Taking a left onto SH146 at a stop sign. Heading southbound. Seeing lots of large trucks on the highway.
10:18 CST	Behind the long line of truck traffic. Increase in particle rate
10:20 CST	Traffic cleared up.
10:21 CST	Excited highway

Time	Notes for September 18, 2023
10:26 CST	Went under the bridge, seeing Kemah, O3 is in low 60s, passing by the boat loading area a min later
10:28 CST	Stopped under a bridge at the intersection of Marina Bay Drive.
10:36 CST	Seeing a drop in O_3, but not much in the area. Rural, not much traffic.
	Westbound transit towards Alvin
10:37 CST	Seeing rise in water, drop in HCHO, taking low 50s for Ox, taking a left onto FM 517 westbound transit
10:39 CST	As we turn HCHO is lower with an increase in H2O. Rad is very low, in the mid to high 300 counts.
10:43 CST	Brief stop at Owens, so far low to mid 50s for O_3, increasing particle rate and consistent HCHO.
10:45 CST	Seeing a lot of particles and NOx we are behind a tractor.
10:46 CST	A dump truck passing us on our left. Particle went up.
10:57 CST	Traffic cleared a bit. Seeing low 60s for O_3.
11:01 CST	Getting closer to Alvin and not seeing O_3 in high 50s low 60s. Little NOx.
	Heading towards Park Place
11:10 CST	Heading north on SH35
11:11 CST	Entering into Chevron gas station. And parked
11:29 CST	Heading out of Chevron gas station.
11:35 CST	Seeing high NOx due to truck upfront.
11:37 CST	Seeing low to mid 60s of Ox
11:42 CST	Winds are very slow. Mid to high 60s for ox. Spraying herbicides right next to us on the sidewalk.
11:46 CST	Badly burning vehicle emissions CO and particle emissions.
11:48 CST	At the intersection, vehicles started accelerating and got increase in CO and NOx.
11:29 CST	Dusty/smoky in front, 18-wheeler several cars ahead.
11:50 CST	Stopped at Sam Houston E Pkwy intersection. Seeing 200 to 300 ppbv of NOx.
11:55 CST	Approaching Hobby Airport O3 in the low 60s
11:58 CST	As we come closer to Hobby seeing inc. In O3/Ox.
11:59 CST	North of Hobby seeing high 70s to 80s of Ox. At the intersection of Dillon and Telephone.
12:00 CST	Seeing some VOCs, MEK, 9 ppbv of HCHO.
12:03 CST	Seeing mid to high 80s of Ox, getting plumes of NOx. With increasing SO2
12:08 CST	Taking I45 north seeing mid 90s of Ox.
12:09 CST	As we get onto I45 we see a drop in HCHO, increased NOx.
12:11 CST	Exiting off of I45. Heading to ERP. Seeing mid 80s
12:14 CST	Parked at ERP.
	Heading west towards 288
12:29 CST	Heading out of ERP leaving with O_3 around 87 ppbv
12:32 CST	At Telephone, going to take a left turn and go under bridge.
12:33 CST	Increased NOx under bridge at Gulf and I45.
12:34 CST	Entering onto I 45.
12:26 CST	Seeing a lot of traffic emissions but Ox should be mid 80s
12:37 CST	Going up bridges clearing of aerosols.
12:43 CST	Getting off on the access road.

Time	Notes for September 18, 2023
12:45 CST	Pushed us back onto the highway. Get off on the next access road. Seeing 100 Ox. Briefly saw close to 100 ppbv of O_3 with 100 ppbv 288 and airport.at traffic light drop in O_3 and HCHO slightly.
12:49 CST	Getting off on the access road. Low 90s for Ox. Dropping of O_3 as we head south of Airport Rd.
12:52 CST	Another stop by the access road seeing mid 80s for Ox. Gradual drop
12:53 CST	Getting onto Beltway 6.
12:54 CST	Taking a right turn on Beltway 8. Seeing mid to high 80s for Ox.
12:57 CST	Mid to high 90s of O_3.
12:59 CST	Heading into a gas station.
13:06 CST	Saw up to 102 ppbv of O_3 at the gas station while we plan trip. Heading back west to grab another transect of O_3.
13:08 CST	Heading out of gas station and west onto Beltway 8 to get to Post Oak Rd.
13:10 CST	Taking a right onto Post Oak
13:15 CST	When we're cleared of NOx.
13:19 CST	Seeing high O_3 up to 110 South Post Oak and Airport.
13:30 CST	Missed our exit. Took 610 east, exit main getting back on Belfort Ave.
13:43 CST	Closer to 110 ppbv of Ox near the intersection of Belfort and Chimney Rock.
13:53 CST	Starting south on Fondren.
14:12 CST	Passing by a power plant. For southwest bound.
14:14 CST	Right onto Sienna Parkway
14:18 CST	Coming into Sugarland seeing an increase in O_3.
14:34 CST	Saw close to 115 ppbv of O_3
15:12 CST	Seeing lower end of O_3 as we're passing I10
15:28 CST	Turning into a parking lot for a restroom break.
15:50 CST	Heading onto 290. Eastbound.
16:19 CST	Big dirty dump truck off the side of us.
17:02 CST	Exiting onto Sens Rd.
17:03 CST	Right onto Sens Rd.
17:15 CST	Heading into La Porte

September 19, 2023

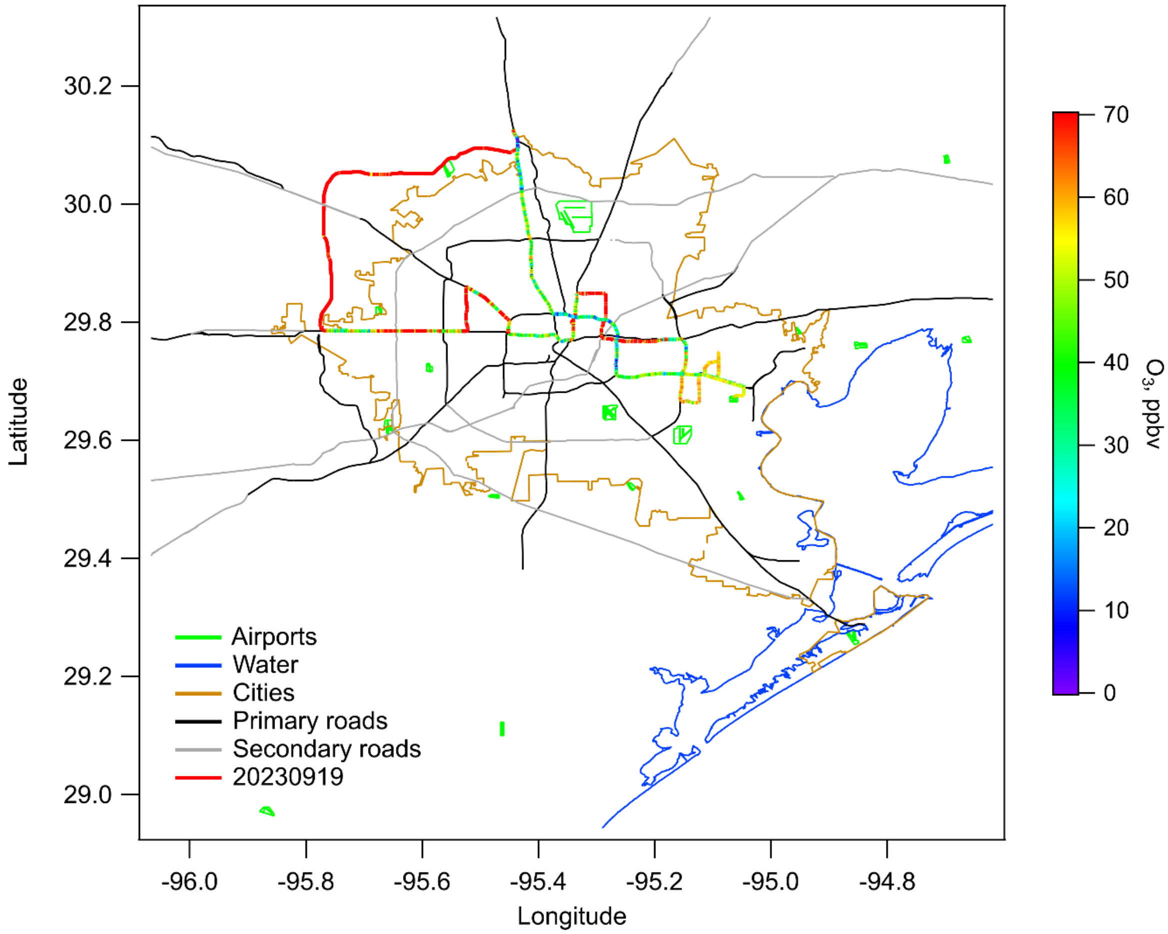

Figure 93. *Spatial plot of mobile measurement of ozone aboard MAQL3 on September 19, 2024.*

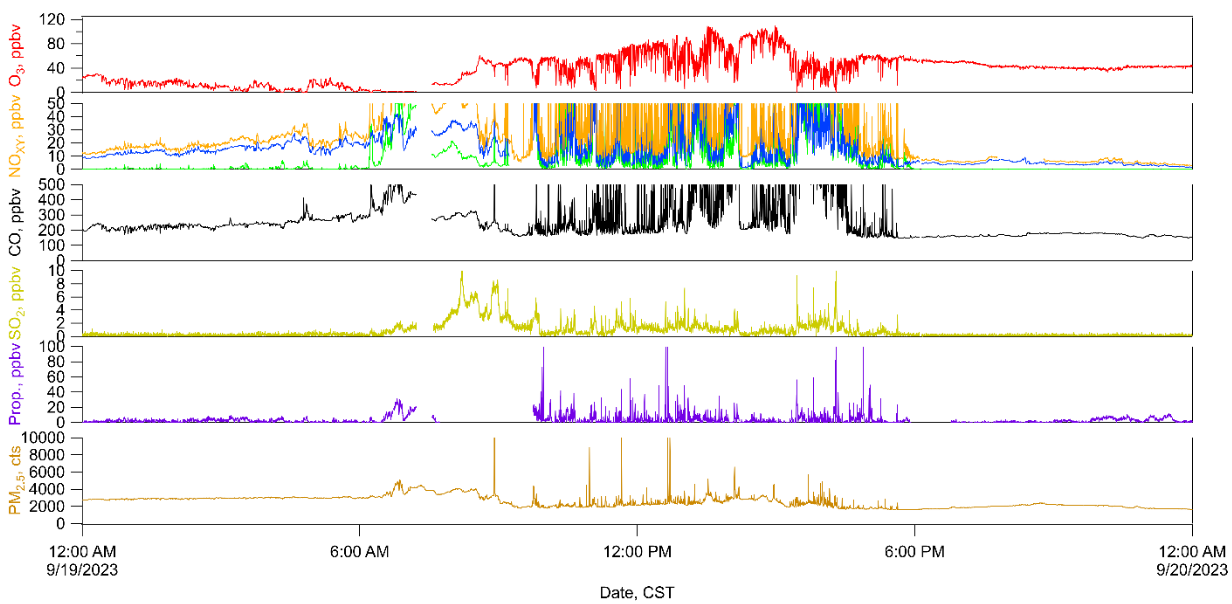

Figure 94. *Time series for selected measurements aboard MAQL3 for September 19, 2024*

Time	Notes for September 19, 2023
09:30 CST	Heading out of La Porte. In the morning, TG span and zero, HCHO zero at the instrument. HCHO zero at the inlet and high span.
09:34 CST	Getting on to H street
09:39 CST	Stopped to take a right on Sens Rd.
09:40 CST	Stopped at L St.
09:43 CST	Stopped by the service road of the highway because NOx was not going.
09:52 CST	Exiting to get onto Independence Pkwy.
	Starting the first transect in the Ship Channel Area
09:53 CST	Starting first drive northbound. So2 less at ship channel than La Porte. SO_2 is with diesel. And ship channel is petrochemical.
09:58 CST	Seeing propene in PTRMS and peaks in RAD.
20:02 CST	Taking a turn at the viewing area and overflow parking.
10:04 CST	Taking a left (westbound) onto Tidal Rd. Seeing some enhancement of particles.
10:07 CST	Seeing slight enhancement in MEK,
10:08 CST	Passing by sludgy lake.
10:11 CST	Seeing an increase in O_3. Continuing left towards the highway.
10:13 CST	Passing by Lubrizol.
10:16 CST	At La Porte freeway and East Blvd. heading east seeing slightly less O_3. (mid 50s)
10:19 CST	Heading to Love's gas station. Turning in at 10:20
11:00 CST	Heading out of the gas station.
	Heading to Center Street.
11:01 CST	Staying on access road 225 westbound.
11:04 CST	Self-sampling while stopping at the traffic light.
11:06 CST	Taking a left onto Center Street.
11:24 CST	Mid 60s in O_3 heading west.
	Heading toward Houston East cams site
11:25 CST	Heading onto Beltway 8 heading north.
11:33 CST	Seeing increase in HCHO, saw some O_3 at mid to high 60s but too much NOx impacting measurements.
11:34 CST	Getting onto I-10. Briefly saw high 60s for Ox.
11:36 CST	Getting off the freeway, free port St. To clear NOx. High 60s low 70s for Ox.
11:38 CST	Taking a left onto Market St. (southbound). Seeing low to mid 70s for Ox.
11:42 CST	Stopped at Normandy St. Seeing mid 70s for O_3. Big bump
11:46 CST	Reading 79 at Park Place.
11:52 CST	Parked by Cinemark to figure out route. Seeing 80 ppbv of O_3.
	Heading west then northbound
11:58 CST	Headed out of Cinemark back onto Market St.
12:10 CST	Crossing over tracks right after seeing low to mid 80s O_3,
12:11 CST	Taking right onto Wayside.
12:13 CST	Gradient of mid to high 70s to low to mid 80s going up north.
12:15 CST	Crossing below trains.
12:23 CST	Stopped by a gas station to check on the noise.
12:27 CST	Leaving the gas station seeing mid 80s on O_3.

Time	Notes for September 19, 2023
	Heading westbound. Winds are picking up
12:31 CST	Taking a left onto Tidwell westbound.
12:33 CST	Seeing low to mid 80s of Ox.
12:36 CST	Still hearing a rumbling noise in the back of the truck.
12:41 CST	Large peak in HCHO and methane as we took the turn to drive on the access road of Highway 69.
12:45 CST	Black smoke on the left of us.
12:46 CST	Seeing high 80s.
12:51 CST	Stopped briefly to check on the noise. Seeing low to mid 90s of O_3.
13:04 CST	Could not identify where the noise was coming from. Saw low 90s of O_3.
13:06 CST	Taking a right onto Jensen Drive to go up to Cavalcade St.
13:09 CST	Back onto the service rod of I9, heading south.
13:11 CST	Back onto I69.
13:13 CST	Heading westward to I10 through downtown traffic.
13:18 CST	A large plume of CO and NOx, traffic from 18-wheelers and dump trucks and normal vehicles.
13:28 CST	Exiting onto Blalock Rd. and Fairbanks.
13:31 CST	110 O_3 at the intersection of saw close to 110 ppbv of O_3
12:41 CST	Going southbound on Blalock seeing high O_3.
13:42 CST	Dropped to mid to high 90s.
	Westbound to 99
13:52 CST	On I10 westbound to get to 99.
14:10 CST	Exiting onto exit 743 for a restroom break.
14:25 CST	Heading back out. Seeing close to 100 ppbv of O_3.
14:27 CST	Heading left onto Colonial
14:29 CST	Heading access road to 99.
14:31 CST	Stopped at Franz Rd.
14:37 CST	Seeing an increase Ox as we go up on 99.
14:50 CST	Increased up to 105 to 106 for Ox, but now going down to mid 90s.
14:52 CST	Truck in front, seeing higher NOx. Getting back
14:54 CST	Exiting letting cars behind us go by.
14:55 CST	Exiting Telge, 105s of
15:20 CST	Approx time, took I45 north by mistake. Turning around to do I45 South, seeing a lot of traffic.
15:58 CST	Onto 610 eastbound.
16:20 CST	An increase in Styrene can smell it. On 225.
16:31 CST	Exiting onto Independence Rd.
16:35 CST	Driving into Love's gas station
16:44 CST	Heading out of gas station
16:46 CST	Heading northbound on Independence Parkway
16:50 CST	Smoky truck in front of us. Trying to keep our distance.
16:54 CST	Saw peaks in RAD and PTRMS for propene and some ch4.
16:57 CST	Taking a left into the viewing area and overflow parking.
17:00 CST	Tidal Rd. right turn.
17:02 CST	VOC samples increase NE winds.

Time	Notes for September 19, 2023
17:06 CST	Overall increases in VOCs.
17:18 CST	Heading back to La Porte
17:20 CST	Stopped off the shoulder of service road to turn the engine on and off due to transmission warning
17:27 CST	Benzene and Xylene increased, and toluene was up before.
17:44 CST	Parked at La Porte

September 20, 2023

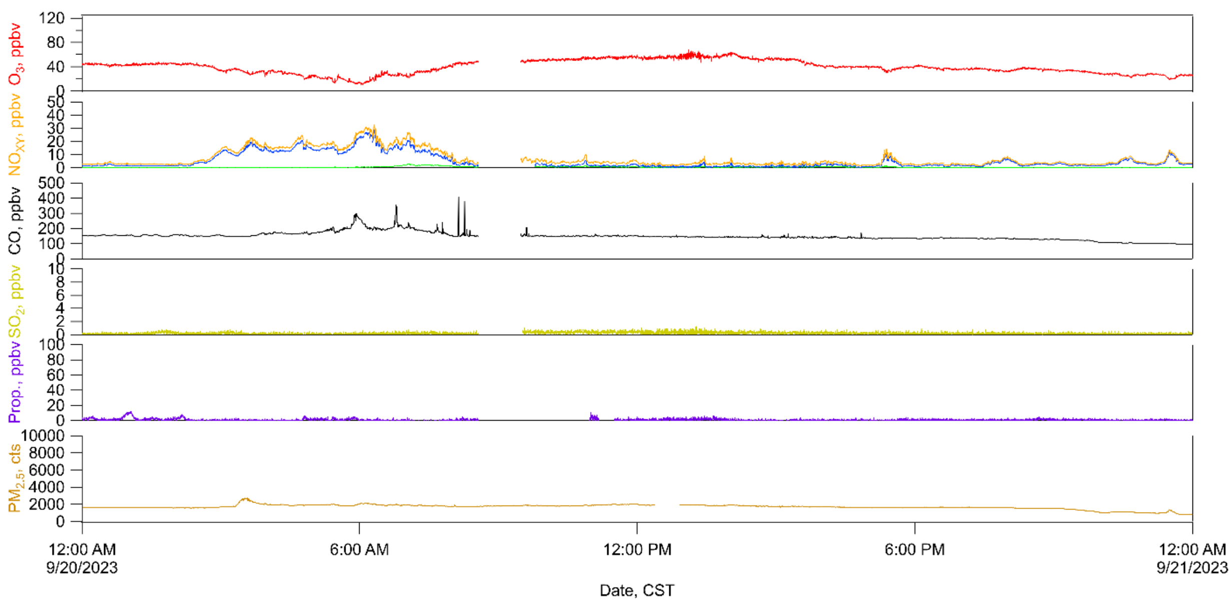

Figure 95. *Time series for selected measurements aboard MAQL3 for September 20, 2024*

September 21, 2023

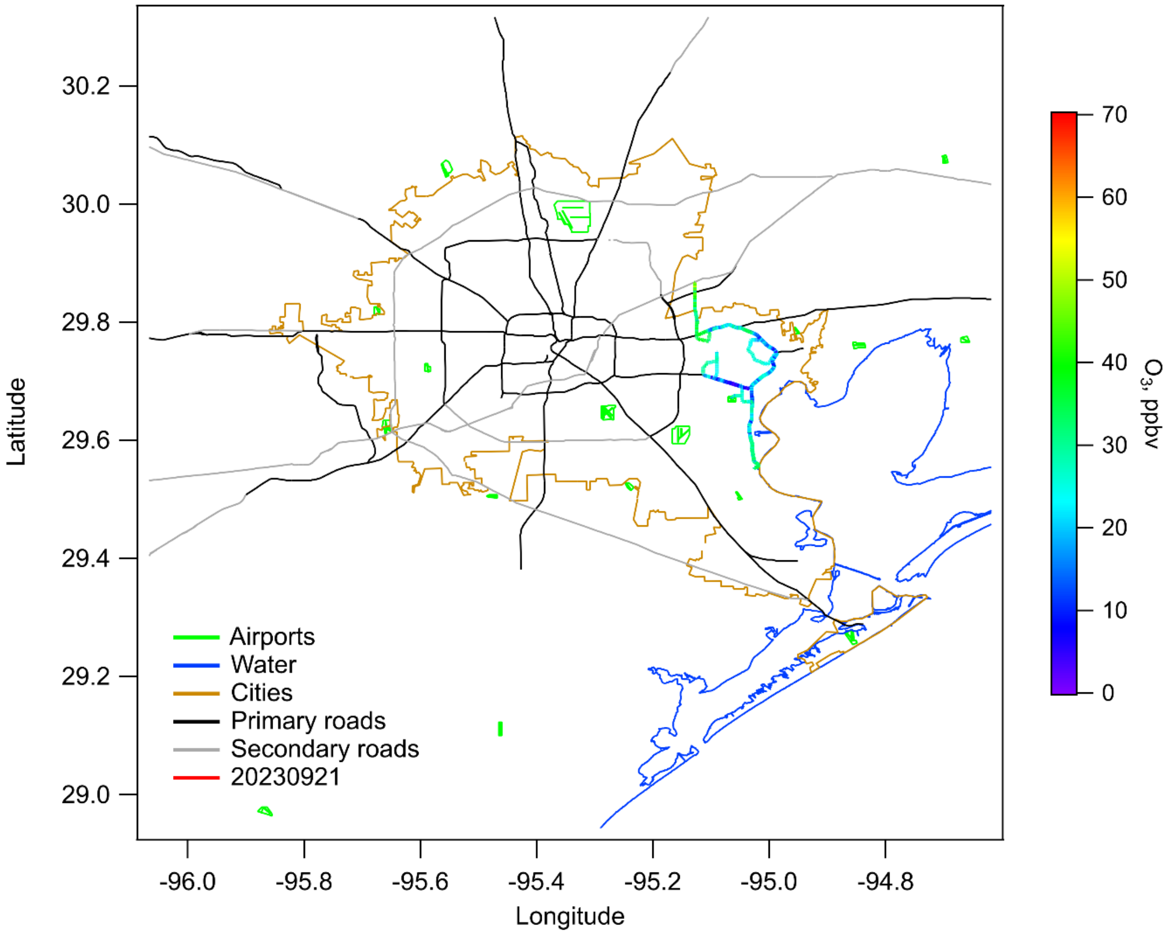

Figure 96. *Spatial plot of mobile measurement of ozone aboard MAQL3 on September 21, 2024.*

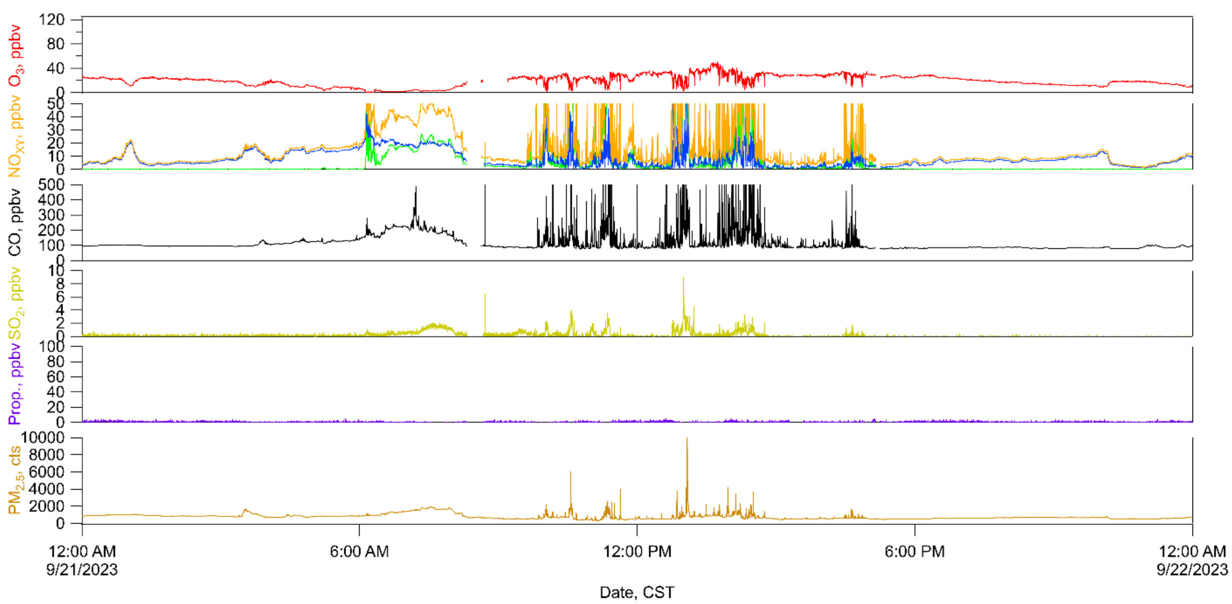

Figure 97. *Time series for selected measurements aboard MAQL3 for September 21, 2024*

Time	Notes for September 21, 2023
	Warm and humid morning
	Filters were changed. new batch of stripping added, HCHO spanned and zeroed.
	Heading to Battleground
09:46 CST	Heading out of La Porte.
09:55 CST	Slow drive on H street.
09:56 CST	Heading onto Sens Blvd.
10:03 CST	Taking a right onto independence pkwy and saw hazmat trucks. Saw some increase in HCHO
10:06 CST	Driving down Independence Pkwy. Seeing peak in HCHO
10:09 CST	Brief stop at Miller cutoff, total energies.
10:10 CST	Big peak of CO, CH4 and HCHO.
10:14 CST	Turning around at overview parking. Heading back on Independence Parkway. Seeing slow climb of O_3
10:18 CST	Taking a right onto Tidal Road northbound.
10:21 CST	Seeing gradual increase in CO, peak in CH4 and gradual increase in HCHO.
10:23 CST	Passing by the "tailing pond" on tidal rd.
10:26 CST	Truck passes by us.
10:27 CST	Passing by Lubrizol 14 plant entrance.
	Heading to Baytown
10:30 CST	Heading toward Baytown, access road on 225 east.
10:52 CST	On 225 east. A lot of NOx. - trucks in front
10:37 CST	Onto highway 146 heading over a bridge north east bound.
10:42 CST	Exiting on Lanier. Taking a left onto Texas. Seeing large flare up ahead.
10:46 CST	On Airhart Drive going over railroad tracks.
10:48 CST	Take a left onto Market St.
10:49 CST	Heading onto Bayway Drive. Passing by Exxon mobile.
10:54 CST	Stopped briefly to let traffic by.
11:00 CST	Taking a left onto Baker Rd. East bound.
11:02 CST	Passing by Monument Chemical on our right seeing some increase in SO_2. Gradual increase in NOx. Downwind of the plants
11:04 CST	At Decker Drive. Decreasing SO_2. Increasing traffic emission.
11:05 CST	Driving on the access road. Of 146
11:11 CST	Heading back onto W. Texas St. To get back on Lanier to head onto the highway.
	Heading to Kemah to swap Sushil and Doug.
11:12 CST	Back onto Highway 146 westbound.
11:22 CST	CO increase with a big truck. CO peak followed by some SO_2.
11:25 CST	Exiting on Red Bluff Rd. Seeing low 30s for Ox.
11:27 CST	Seeing large peaks in CO. Not much NOx. Continuing onto the access road.
11:30 CST	Heading to the intersection at Webster.
11:32 CST	Underneath the bridge.
11:34 CST	Taking a left onto Toddville Rd.
11:36 CST	Heading into the marina, underneath the bridge.
11:37 CST	At the marina gate.
11:40 CST	Parked.
	Heading to Channelview – K-Solv

Time	Notes for September 21, 2023
12:26 CST	Settled back in and will be heading out with o3 in the low 30s/
12:35 CST	Big peak in CO not much NOx. Stopped at traffic light more regular vehicles.
12:55 CST	Transferring onto 330 Northbound.
13:01 CST	SO_2 peaked up to 9 ppbv - same peak in TAP check to see where this plume is
13:04 CST	Passing by benzene barge. Benzene peak but likely due to passing trucks.
13:05 CST	Exiting onto Bayout Drive and heading onto Market St.
13:08 CST	Turning onto Lakeside Drive.
13:12 CST	Close to the K-Solv plant, SO_2 peak, benzene is high.
13:18 CST	Stopped Market St.
13:19 CST	Taking a left onto Sheldon (northbound)
13:31 CST	Downwind of Equistar/United Ways. (LyondellBasell. Olefins. Not seeing much in trace gases.
13:34 CST	Seeing a gradual increase in NOx, a gradual increase in VOC.
13:36 CST	Jump in O_3 about 5 ppbv and jump in HCHO.
13:39 CST	Waited to get on the left lane due to a big dip in the road.
13:41 CST	Heading into a Texaco to make a U-turn
	Turning back towards K-Solv.
13:43 CST	Seeing an increase in O_3 again.
14:00 CST	Stopped at school crossing - Joe Frank Campbell
14:08 CST	Taking a left onto IH10
14:11 CST	Big peak in VOCs.
	Heading to Marina
14:19 CST	changing highways. Westbound on I10
14:44 CST	heading into Marina

September 22, 2023

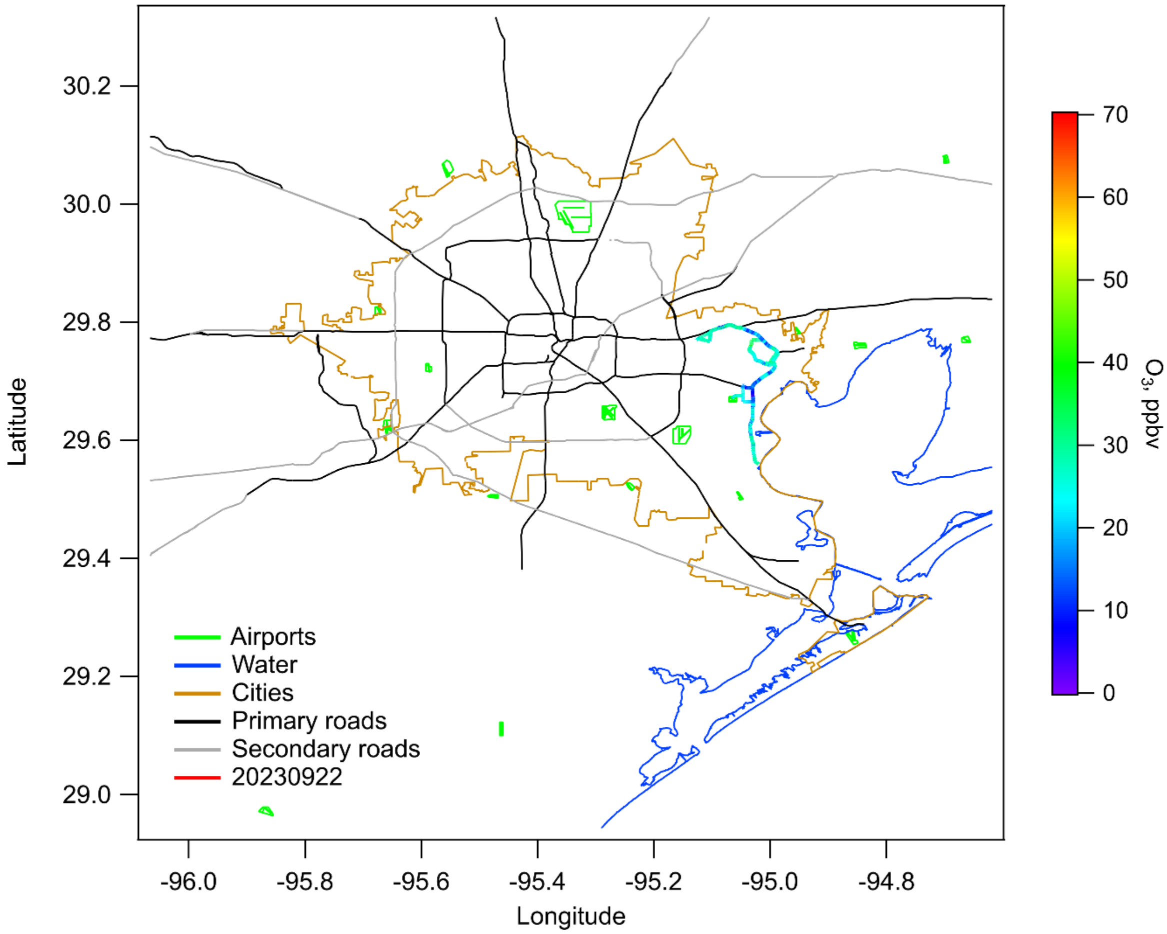

Figure 98. *Spatial plot of mobile measurement of ozone aboard MAQL3 on September 22, 2024.*

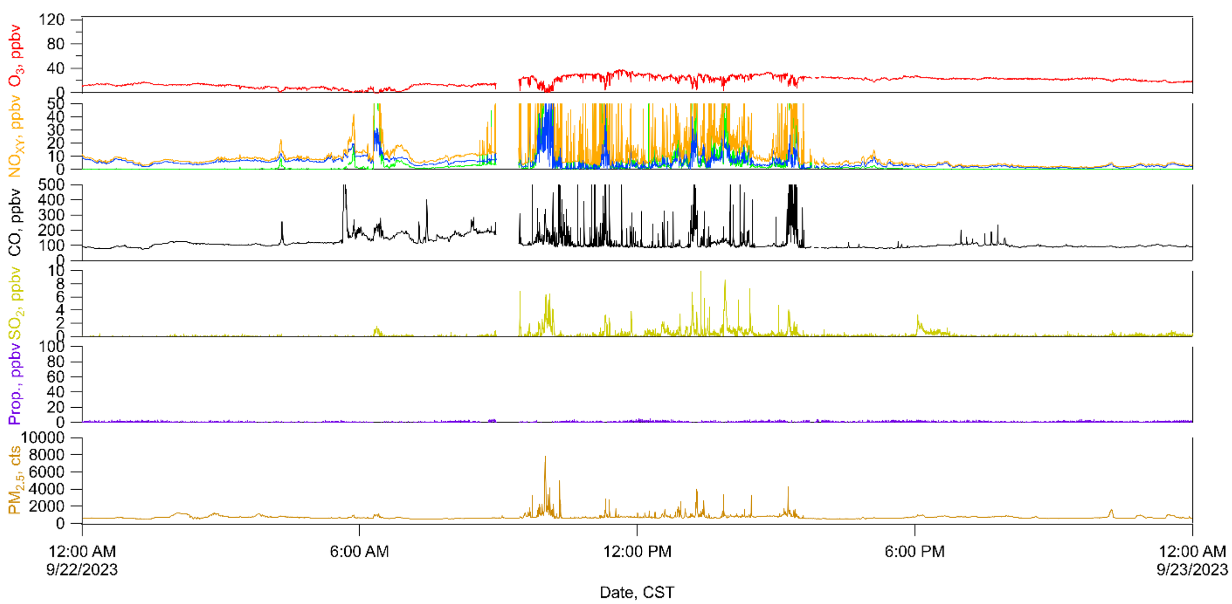

Figure 99. *Time series for selected measurements aboard MAQL3 for September 22, 2024*

Time	Notes for September 22, 2023
09:46 CST	Heading towards Sens Rd. On H street.
09:51 CST	Taking a left to get onto the highway
09:54 CST	Parked at gas station swift
10:08 CST	Heading out of the station
10:09 CST	Heading back on to SH146
10:25 CST	Parked and waiting at Main Street by Clear Lake. Making new plans
	Meeting at K-Solv. (storm forming so boat going back to Kemah, MAQL3 will do runs at Baytown)
10:41 CST	Making a U-turn at Main Street and heading towards Baytown.
10:48 CST	Driving into Shell
11:20 CST	On eastbound SH146 towards Baytown on the bridge. Right before saw a big ethene peak.
11:24 CST	Exiting onto W. Texas Ave. Low 30s for ox as NOx has cleared.
11:26 CST	Left onto Airhart Drive. Currently upwind of facilities.
11:29 CST	Bumpy crossing on the railroad.
11:31 CST	As we head to Market St and Airhart. Seeing a gradual increase in O_3 and NOx.
11:34 CST	Slow driving 20 miles an hour. Upwind. Seeing increase
11:36 CST	Spike in VOCs. Downwind of Mitchell Bay and facilities near it.
11;38 CST	Winds have switched from the east now.
11:29 CST	SUV passed us on the road, saw a spike in CO.
11:45 CST	Drop of O_3 to low to mid 30s, with low NOx. Left onto Baker.
11:28 CST	Gradual increase in NOx. We are downwind of the plant. Some traffic but looks very gradual.
11:49 CST	At Decker Drive. Low NOx and low to mid 30s of Ox.
11:50 CST	Turned right onto the access road passing by Enterprise.
11:54 CST	At Rollingbrook Drive. Stopped seeing local traffic which cleared out quickly.
	Second run at Baytown.
12:01 CST	Upwind wide of facilities on Airhart St. Crossed over railroad tracks. Bumpy.
12:03 CST	Right onto Market St.
12:06 CST	Starting Bayway.
12:09 CST	Winds are from facilities b Mitchell Bay. Increase in VOCs.
	Bayway Drive southbound
12:14 CST	Taking a left onto the nature reserve. Difficult U-turn back onto Bayway Drive.
12:20 CST	Seeing increased NOx measurements, and slightly elevated SO2.
12:22 CST	Barges, we are directly downwind. Seeing increased NOx.
	Northbound on Bayway Drive
12:29 CST	Taking a left onto Market to go back up north on Bay Way Drive
12:30 CST	Taking a left back onto Market Street to get to Bayway Drive.
12:31 CST	Starting Bayway Drive transect northbound crossed over railroad tracks.
12:32 CST	SO_2 increased gradually but then got our exhaust briefly.
12:33 CST	Letting an SUV and truck pass us.
12:37 CST	Letting the vehicle pass us.
	Southbound on Bayway Drive

Time	Notes for September 22, 2023
12:42 CST	Turning into North Street to make an U-turn back onto southbound on Bayway Drive
12:49 CST	22 ppbv of NOx. Peak but no CO, efficient burning... Saw aerosol peak with the NOx peak
12:53 CST	Took a left onto Market Street. Still saw elevated NOx. Drop in NOx.
12:56 CST	Stopped in front of a parking lot briefly to make plans.
	Heading to Channelview
13:04 CST	Continuing onto Market Street
13:07 CST	Going onto SH146
13:11 CST	Downwind of facilities, seeing an increase in SO_2. Elevated roadway section.
13:17 CST	Exiting highway. Onto Magnolia Street.
13:21 CST	Big truck in front brought up some dirt from the road.
13:23 CST	Taking a left onto Lakeside Drive. Seeing lots of barges downwind of an oxidizer.
13:28 CST	Seeing a smoker right in front.
13:28 CST	NOx is low as we head away from the barge.
13:30 CST	Passing by hazmat shipping containers.
13:31 CST	Seeing an increase in SO_2 pulling north of the container facilities.
13:32 CST	Stop sign and made a left onto Market Street.
	Round two of K-Solv.
13:52 CST	Truck passes by at gas station and SO_2 spiked
14:02 CST	Heading out of gas station
14:06 CST	Taking a right onto Lakeside Dr. There is traffic coming in.
14:11 CST	Activity on barges. SO_2 is increased
14:12 CST	Passing K-Solv plant.
14:15 CST	Taking a left onto Market Street.
14:16 CST	Inside gas station.
	Round three of K-Solv
14:18 CST	Back out of the gas station now at Lakeside Drive.
14:26 CST	SO_2 increased to about 10 ppbv.
14:30 CST	Stopped at a park. Waiting for call.
	Continuing out to head to La Porte to see if we see plumes from the barge.
15:01 CST	Heading out of the parking lot.
15:03 CST	SO_2 peak of about 3 ppbv.
15:05 CST	Saw an increase in NOx with aerosol.
15:08 CST	Sulfur smell. VOCs are measured... Some aerosols, some enhancement of NOx.
15:10 CST	Passing by channel view fleet services, saw some increase in VOCs.
15:11 CST	Taking a left onto access road. Back on
15:14 CST	Heading onto Bayway Drive.
15:26 CST	Exiting onto Sens Rd.
15:27 CST	Getting onto Sens Rd.
15:30 CST	Right onto H street
15:39 CST	Entered into la Porte
15:41 CST	Backing into the parking area at La Porte

September 23, 2023

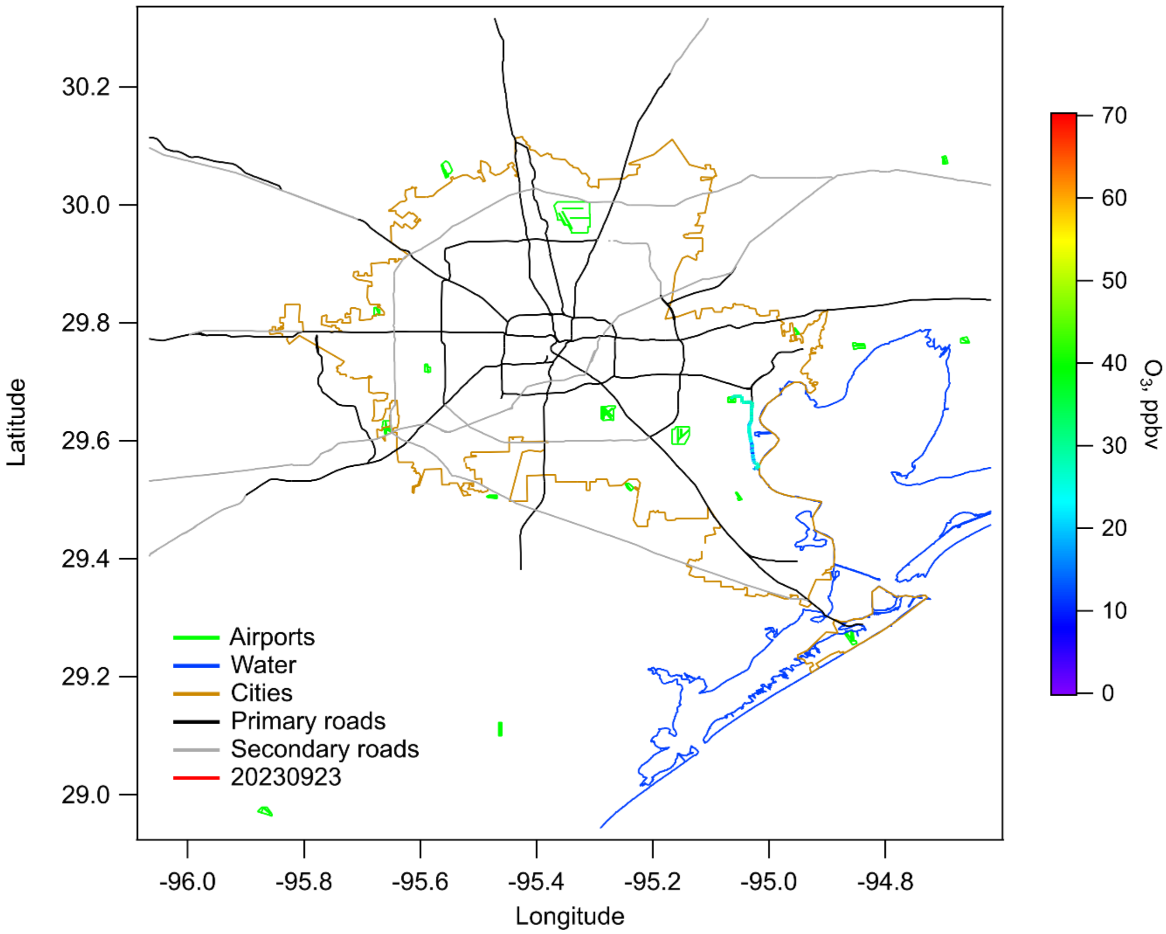

Figure 100. *Spatial plot of mobile measurement of ozone aboard MAQL3 on September 23, 2024.*

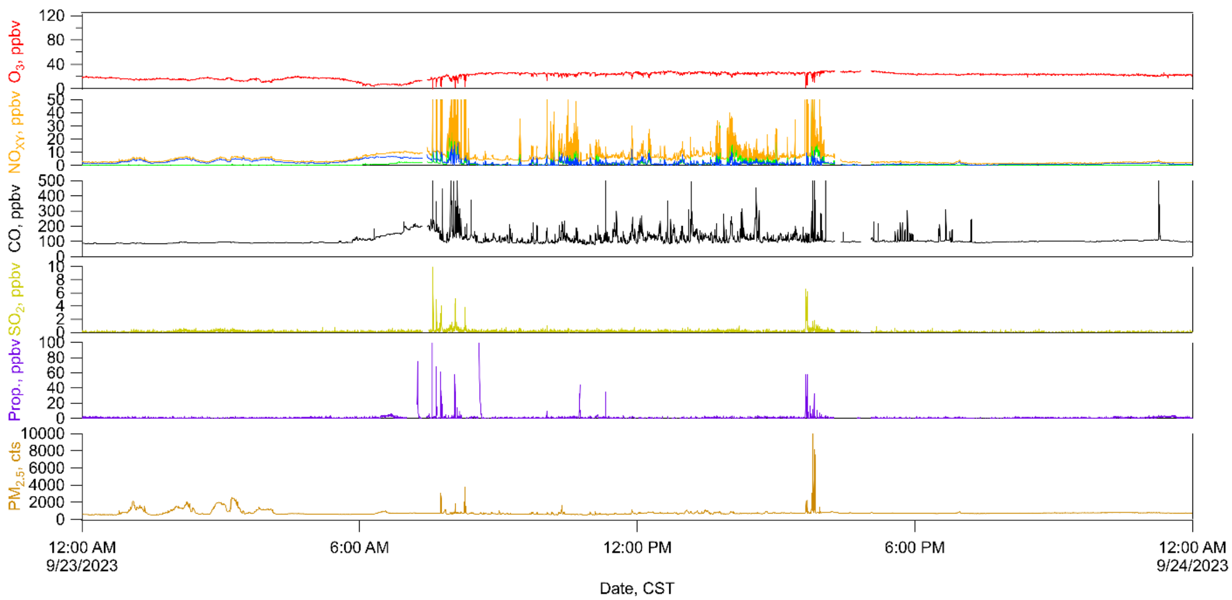

Figure 101. *Time series for selected measurements aboard MAQL3 for September 23, 2024*

Time	Notes for September 23, 2023
07:53 CST	Right turn onto Sens rd.
07:57 CST	Onto SH 146 south bound to Kemah
08:02 CST	Exited on Red Bluff Rd.
08:04 CST	Behind a dump truck saw almost 7 ppbv of SO2. Also with RAD.
15:32 CST	Finished intercomparison.
15:45 CST	Driving on access rd. Up to highway sh146
15:56 CST	Stopped at Spencer St.
16:13 CST	Parked at La Porte

September 24, 2023

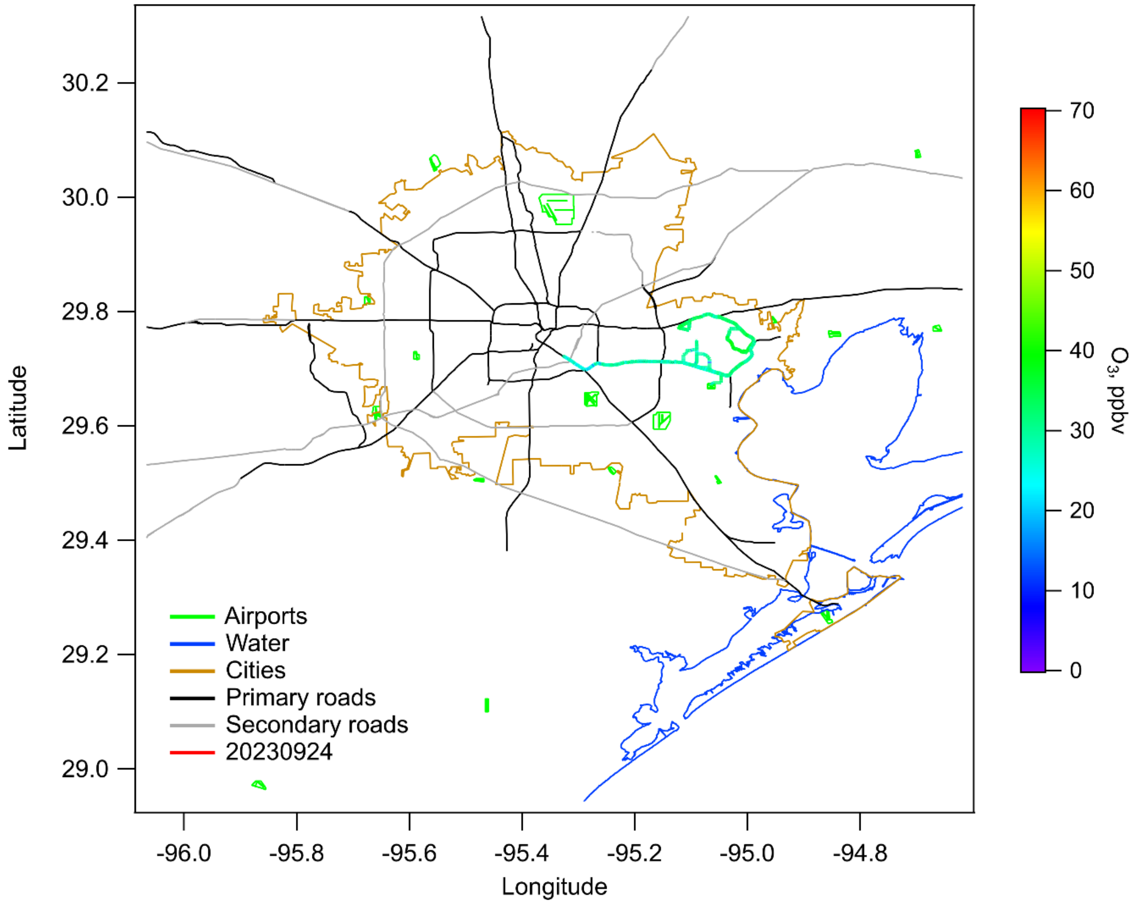

Figure 102. *Spatial plot of mobile measurement of ozone aboard MAQL3 on September 24, 2024.*

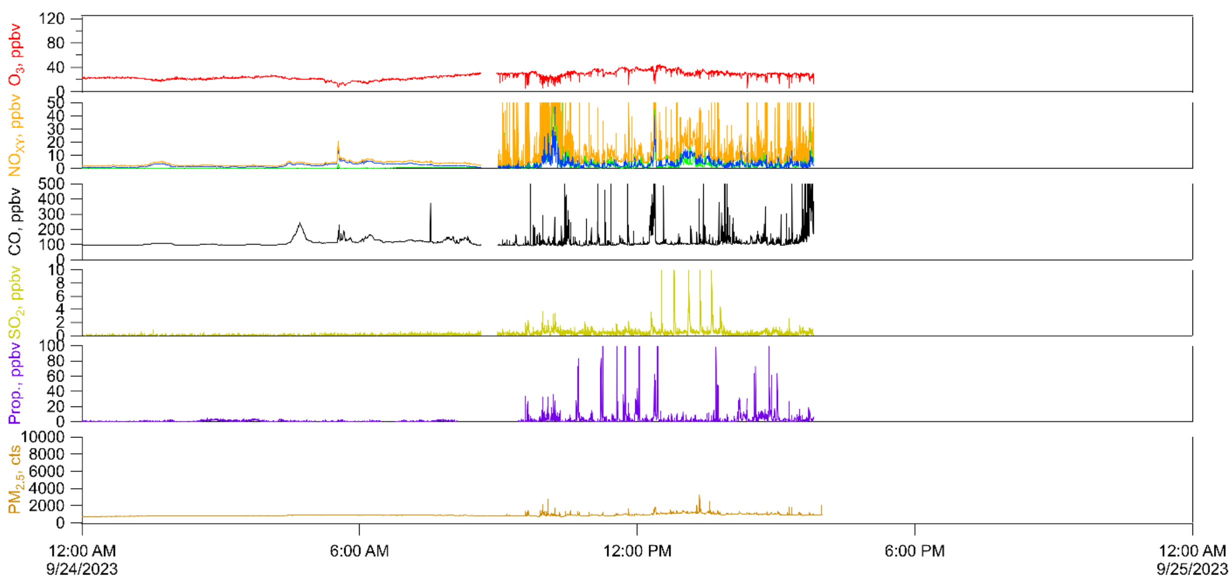

Figure 103. *Time series for selected measurements aboard MAQL3 for September 24, 2024*

Time	Notes for September 24, 2023
	Morning TG spans and zeros, HCHO refill of solutions, and zero.
10:18 CST	Out of La Porte to go to Baytown. Was self-sampling while parked
10:22 CST	Heading onto Highway 225 eastbound.
10:32 CST	Exited at W. Texas
	First pass of Baytown
10:34 CST	Turned onto air S. Airhart drive. Seeing some elevated NOx and a large peak in xylene. Winds are southerly, maybe seeing stuff from the ship channel.
10:37 CST	Bad bumpy railroad crossing.
10:39 CST	Heading onto Market St.
10:41 CST	Heading right on Bayway seeing the flare. Currently upwind. Seeing an increase on RAD.
10:45 CST	Strong spike truck passing.
10:46 CST	Based on wind sock winds are southwest winds.
10:49 CST	Driving faster, not seeing much.
10:51 CST	Saw some NOx and VOCs increase as cars passed us by the rd.
10:53 CST	W. Baker Rd. Saw an increase in NOx and a small enhancement in SO_2 right before the turn.
10:54 CST	CO peak with truck passing by.
10:55 CST	Passing by Monument Chemical Plant.
	Second pass on Baytown
10:56 CST	Passed railroad track.
10:57 CST	Stopped in front of Decker, light traffic. Brief self-sampling before turning right onto the access rd.
10:58 CST	On the access road, we're seeing an increase in propene and HCHO
11:09 CST	Heading back onto Airhart Drive seeing inc. Traffic.
11:10 CST	Market St. Right turn.
11:39 CST	Left onto Bayway Drive seeing a huge increase in RAD
11:14 CST	Seeing another huge peak in RAD, xylene.
11:17 CST	Seeing methane peak near the pipeline
	The third pass is just on Bayway Drive (southbound)
11:22 CST	Turning around at a Wooster church.
11:28 CST	Methane peak (5 ppm) with a pipeline
11:30 CST	Seeing boats go by the channel.
11:33 CST	Strong smells with RAD. With increasing SO_2. HCHO also increased.
11:34 CST	Passing by San Jacinto Street.
11:36 CST	Exiting Bayway to do a loop.
11:37 CST	Taking a left back onto Market St.
	Fourth pass just on Bayway Drive (northbound)
11:39 CST	Taking a right back onto Bayway Drive.
11:40 CST	Railroad crossing.
11:42 CST	Gradual rad increase. Ligurian sea - ships nearby at the channel.
11:44 CST	Large peak in RAD
11:45 CST	Kinder Morgan oil and gas pipeline seeing an increase in Methane.

Time	Notes for September 24, 2023
11:47 CST	Crude oil signs on the right and hot rod pass by with CO increase and a small peak in RAD.
11:50 CST	Passing by pipeline (petroleum, butadiene, hydrogen).
	Fifth pass just on Bayway Drive (southbound)
11:52 CST	Right onto North St. Ceilometer error again. Close and open working now (second time today)
11:56 CST	Seeing some NOx from the road. Seeing some increase in NOx, climbing.
11L57 CST	Diesel pickup go by.
11:58 CST	Seeing a gradual increase in NOx and elevated with aerosols.
11:29 CST	Methane peak near the pipeline.
12:00 CST	Seeing some elevated RAD and also increased (Exxon products 2,3,5 facility)
12:01 CST	Methane increases as we pass pipelines.
12:02 CST	RAD increase
	Heading to K-Solv plant
12:08 CST	Heading left onto Airhart Drive
12:10 CST	Bad railroad crossing, not much NOx and
12:14 CST	At Decker to get onto the highway. 330 westbound
12:18 CST	Seeing SO2 and HCHO saw some increase. - low NOx. We were on an elevated highway passing by the facilities.
12:22 CST	Seeing an increase of HCHO and methane and inc. Aerosols, with benzene also.
12:23 CST	Exited and now on winds coming towards us from the bay we are on Market Street.
12:26 CST	Alkene peak. Passing by asphalt facility.
12:27 CST	Smells like sulfur,
12:28 CST	Bad roads slow drive.
12:31 CST	Seeing a sharp peak in SO_2 (9 ppbv).
12:34 CST	Very sharp CO peak with nothing else.
	First pass to K-Solv
12:36 CST	Took a left lane onto De Zavala Rd.
12:38 CST	Seeing elevated NOx as we get closer to K-Solv.
12:40 CST	NOx is less noisy and going down. Turning left onto Lakeside Drive. Seeing VOCs.
12:43 CST	Seeing aerosol and NOx increasing.
12:48 CST	Another huge SO_2 peak in a similar area as the first.
	Second pass to K-Solv facilities.
12:50 CST	Stopping to swap with Alex
15:52 CST	Resume driving
12:55 CST	Seeing elevated NOx
12:57 CST	Passing coast guard approved training center
13:06 CST	Strong SO_2 peak when rounding the corner by the boat ramp. Broader plume than last pass.
13:07 CST	Turning left onto Market Street.
	Third pass to K-Solv facilities
13:10 CST	Methane peak of 3.7
13:11 CST	Turning left onto De Zavala Rd.

Time	Notes for September 24, 2023
13:13 CST	Passed Coast Guard training facility
13:14 CST	Rounding a corner in front of K-Solv
13:16 CST	Decrease in NOx to about 3 ppb.
13:17 CST	NOx and small CO peak.
13:20 CST	NOx and CO peak from SUV passing us.
13:21 CST	Barge pushing north. Rounding the corner by the boat ramp.
12:22 CST	Just passed through the SO_2 plume seen the last two times. Up to 23 ppb. Turned left onto Market Street.
	Fourth pass to K-Solv
13:26 CST	Turned left onto De Zavalla St.
13:28 CST	NOx trends were similar to the last 3 passes. Slightly elevated and noisy-looking around 10 ppb.
13:29 CST	Boat and PTR are seeing peaks and broader elevations (small) of Benzene.
13:35 CST	SO_2 peak started. Same location next to tugboats. Smaller magnitude 10 ppb. Sharp NO peak up to ~60 ppb.
13:38 CST	Received pictures of M3 from the boat. The boat was nearby for the fourth pass.
	Heading back toward Battleground
13:41 CST	Pulled over briefly to allow a truck with a boat to pass by.
13:42 CST	RAD peak up to 1000 counts
13:43 CST	RAD had a small increase to about 500 ppb, which coincided with the NOx peak. May have self-sampled while rounding the corner.
13:45 CST	Back on the highway.
13:48 CST	SO_2 peak while on the highway. 4 ppb.
13:55 CST	Crossing 146 bridge. Saw MAQL-sea boat underneath.
14:00 CST	Exiting the highway at Miller cut-off
	Battleground sampling at Miller Cut-off
14:03 CST	Turned left onto Strang Road
14:04 CST	Methane peak 6.6 ppm
14:05 CST	Passing over train tracks.
14:06 CST	Passing propylene station but it is downwind of us.
14:08 CST	Concluded Miller cut pass. Did not see much of anything.
	Battleground
14:10 CST	Passed by Loves
14:11 CST	Methane peak 2.6 ppm. Propene peak 8000 counts
14:13 CST	RAD has had slightly elevated counts since turning onto Independence Parkway. ~400 counts.
14:14 CST	Elevated NOx.
14:16 CST	UH HCHO instrument seeing increased HCHO 4 ppb.
14:23 CST	NOx peak to ~60 ppb. Started with a vehicle but no other vehicles to explain continued high levels.
14:28 CST	Driving along the highway again
	Full pass by battleground
14:29 CST	Passing Love's gas station again

Time	Notes for September 24, 2023
14:32 CST	Methane 2.5 ppm. Turning around to head back to the gas station.
14:35 CST	Entering gas station. Idling.
14:46 CST	Leaving the gas station.
	Second attempt at a full pass of the battleground
14:48 CST	Back on Independence Parkway.
14:51 CST	Methane 2.9 peak, propene 5000 counts, also ethene spike a little before.
14:53 CST	Passing La Porte polypropylene plant. NOx increasing to ~10 ppb.
14:55 CST	Methane peak 3.1 ppm
14:58 CST	Made U-turn. NOx peak likely self-sampled.
15:01 tur	Ned right onto Tidal Road.
15:02 CST	Methane and HCHO peak. HCHO peak at 3.6 on Picarro. Also saw a sharp NOx peak.
15:04 CST	85 ppb noy, 45 ppb NOx in a sharp peak.
15:05 CST	UH HCHO instrument up to 5.1 ppb.
15:13 CST	End of loop

7. Appendix B: Task 4 – Offshore Air Quality Measurements daily figures and field notes

September 6, 2023

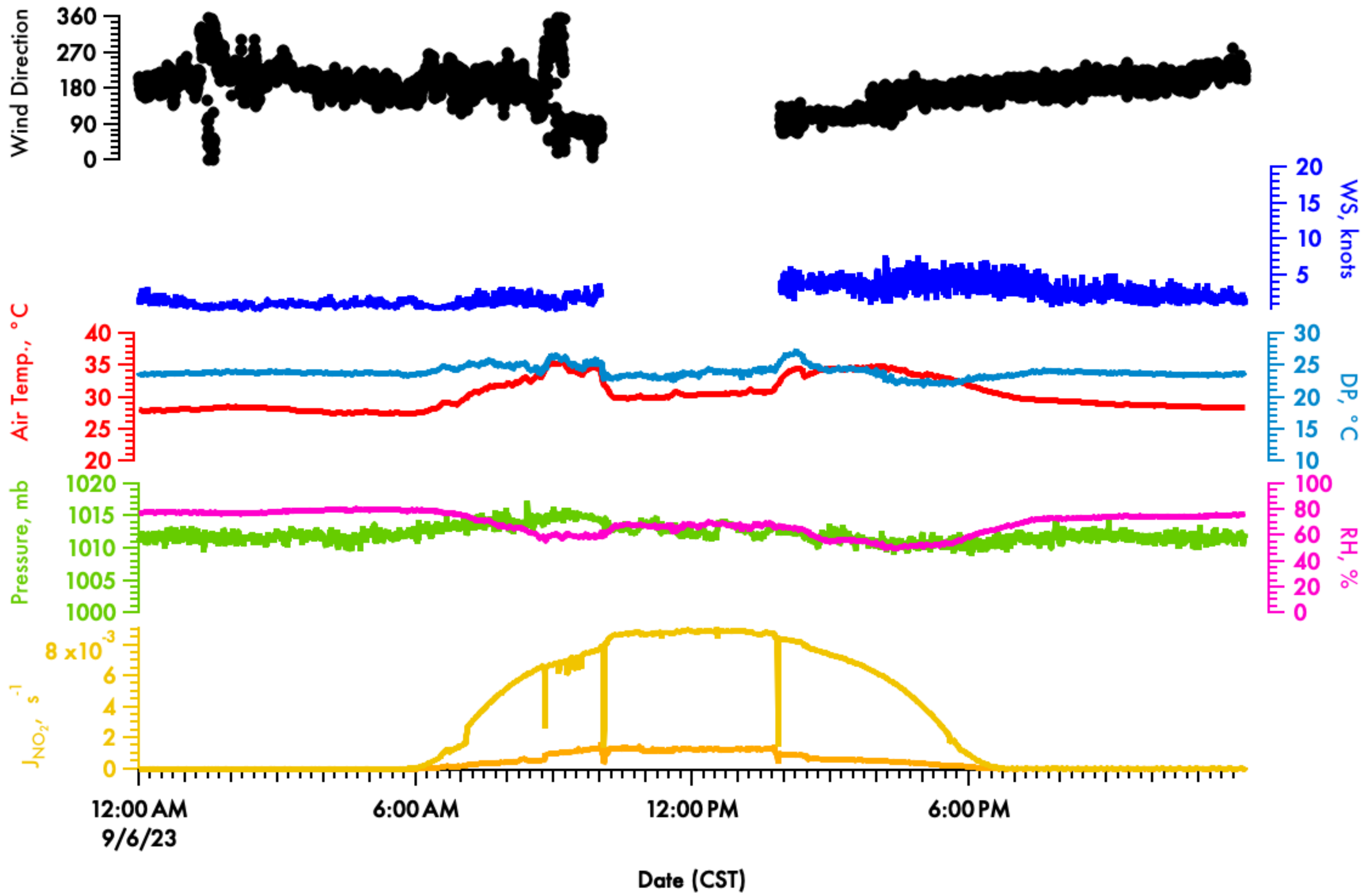

Figure 104. *Meteorological measurements collected from the MAQL-Sea boat platform on 6 September 2023.*

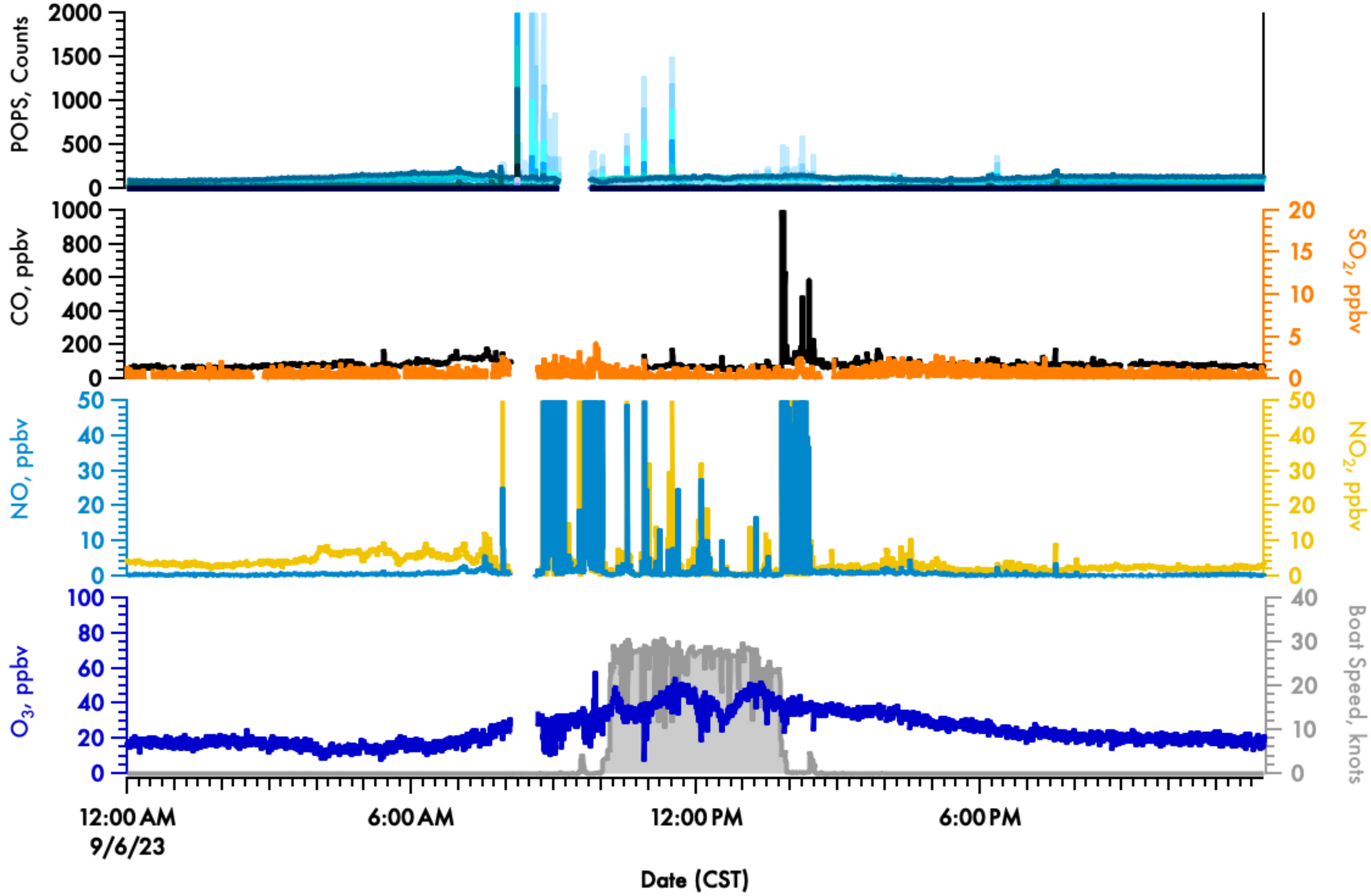

Figure 105. *Trace gases and POPS measurements collected from the MAQL-Sea boat platform on September 6, 2023.*

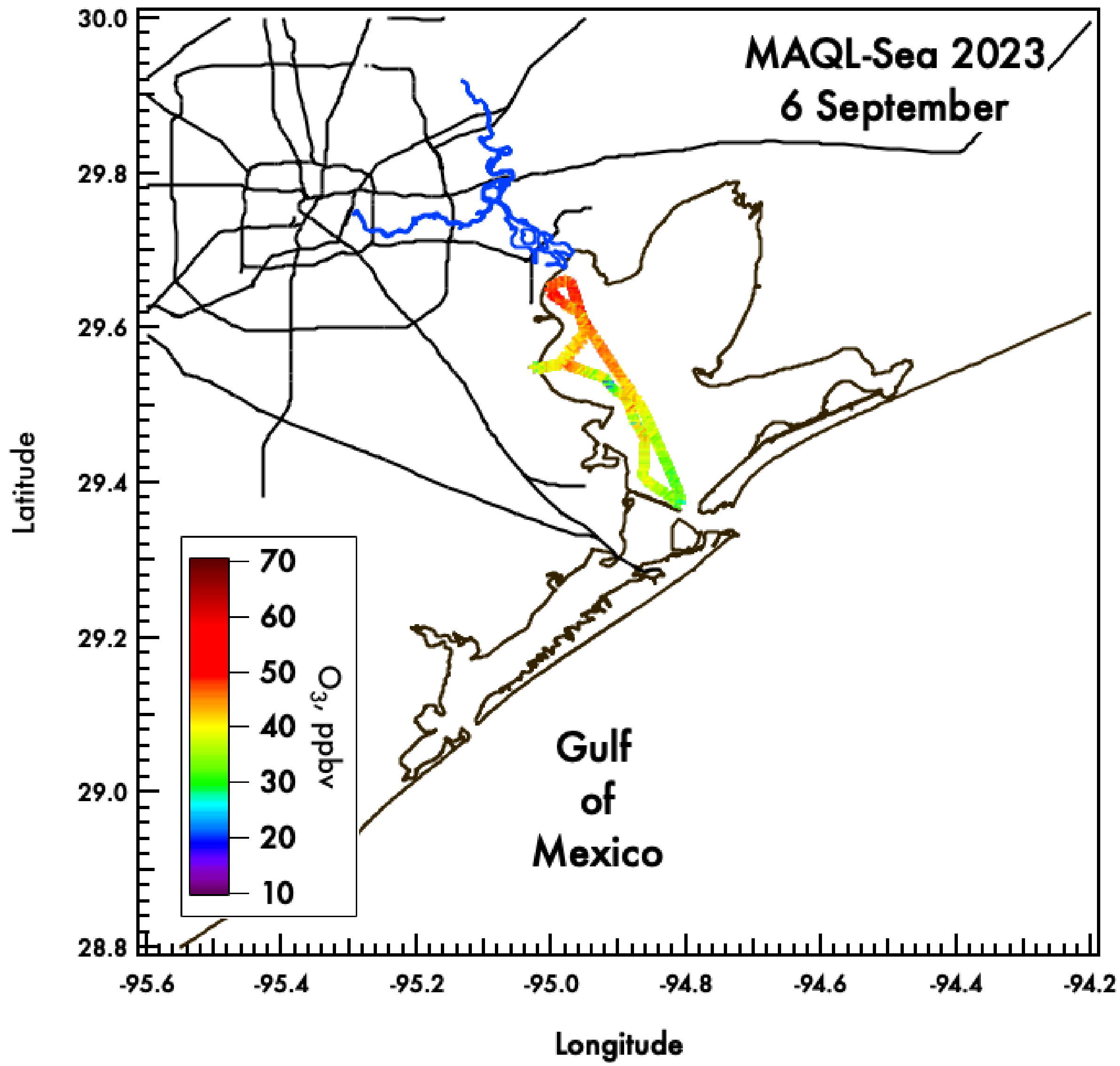

Figure 106. *Spatial plot of mobile measurement of ozone aboard MAQL-Sea boat platform on September 6, 2024.*

September 7, 2023

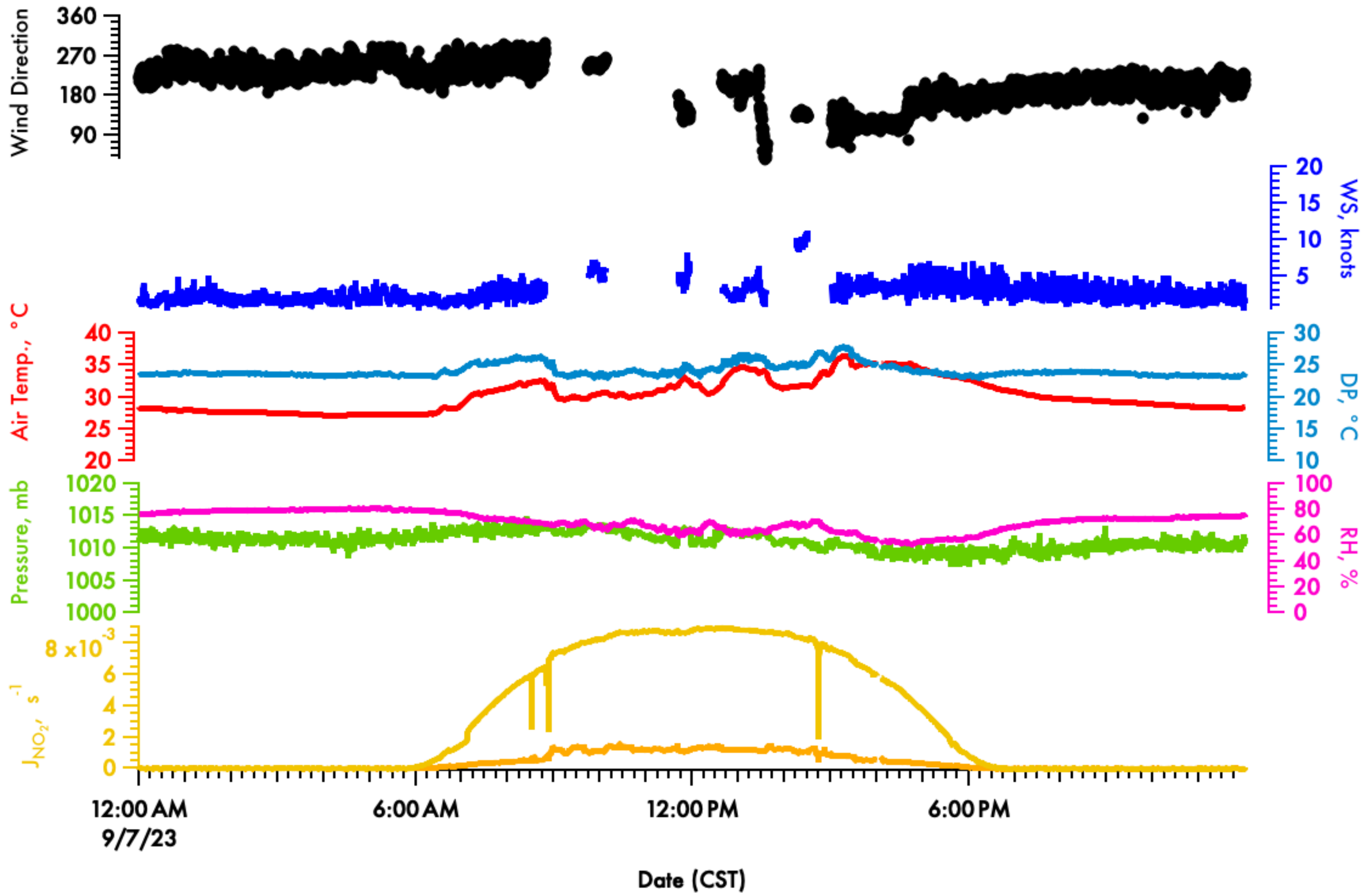

Figure 107. *Meteorological measurements collected from the MAQL-Sea boat platform on 7 September 2023.*

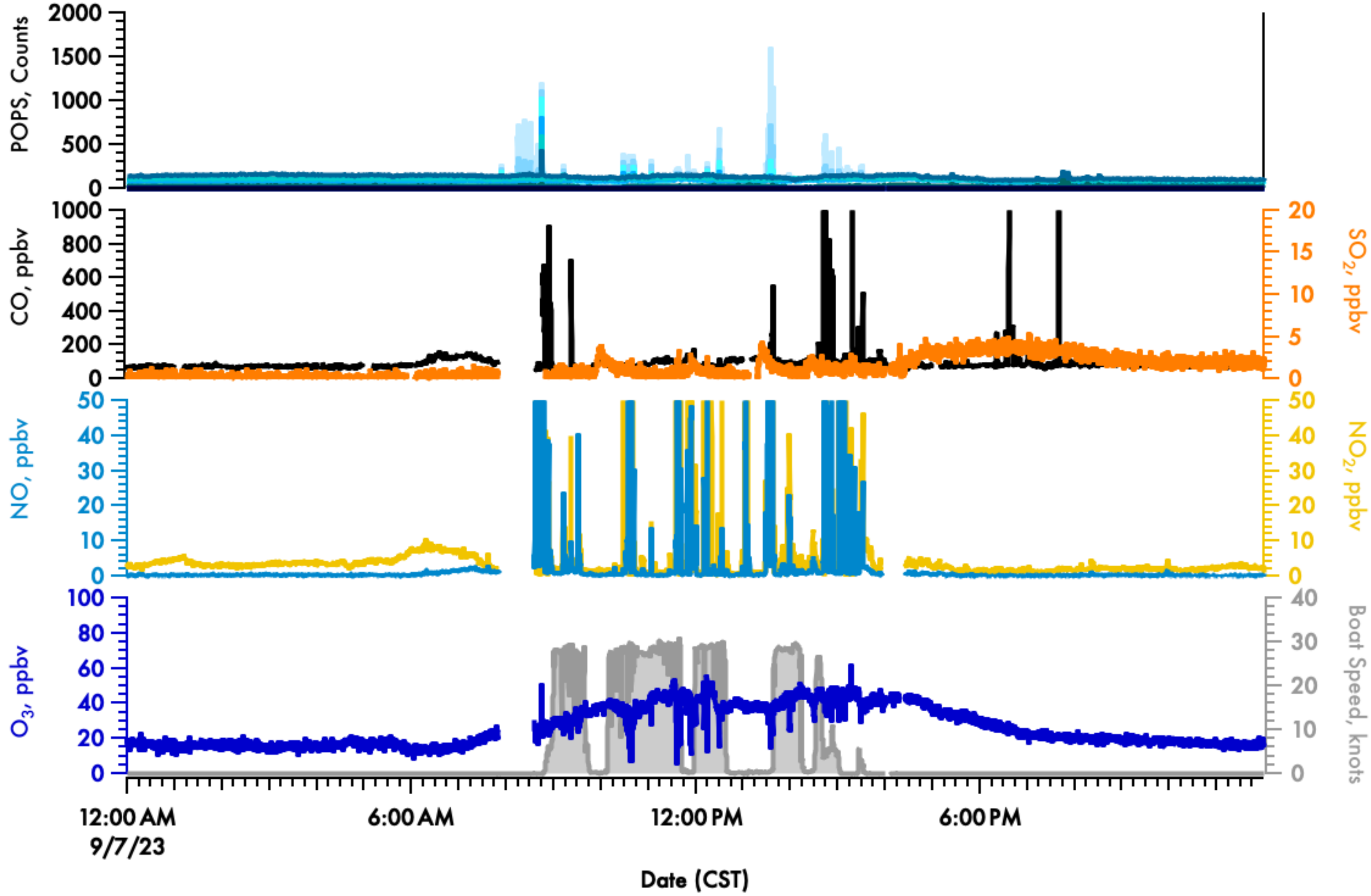

Figure 108. *Trace gases and POPS measurements collected from the MAQL-Sea boat platform on September 7, 2023.*

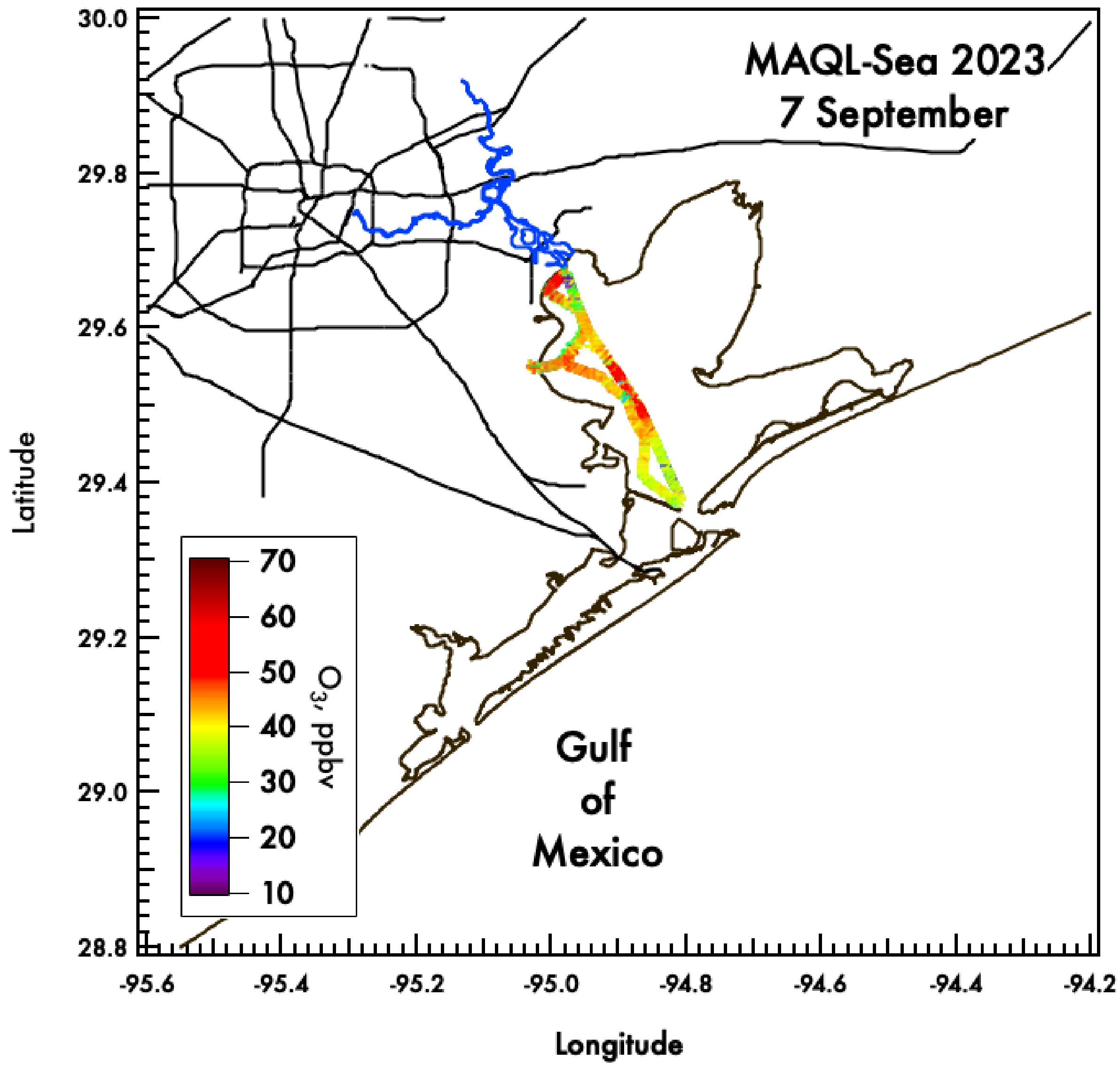

Figure 109. *Spatial plot of mobile measurement of ozone aboard MAQL-Sea boat platform on September 7, 2024*

September 8, 2023

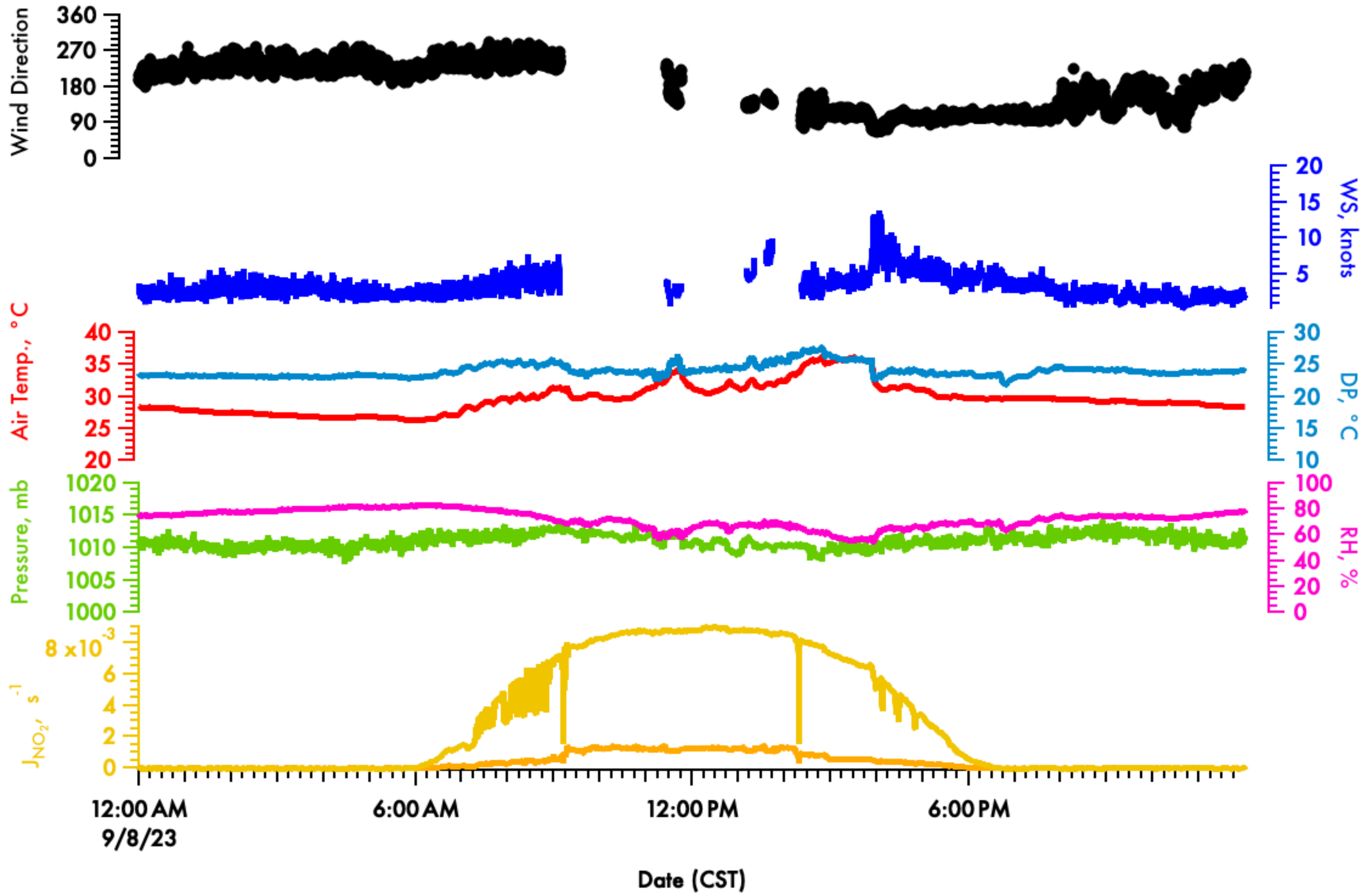

Figure 110. *Meteorological measurements collected from the MAQL-Sea boat platform on September 8, 2023.*

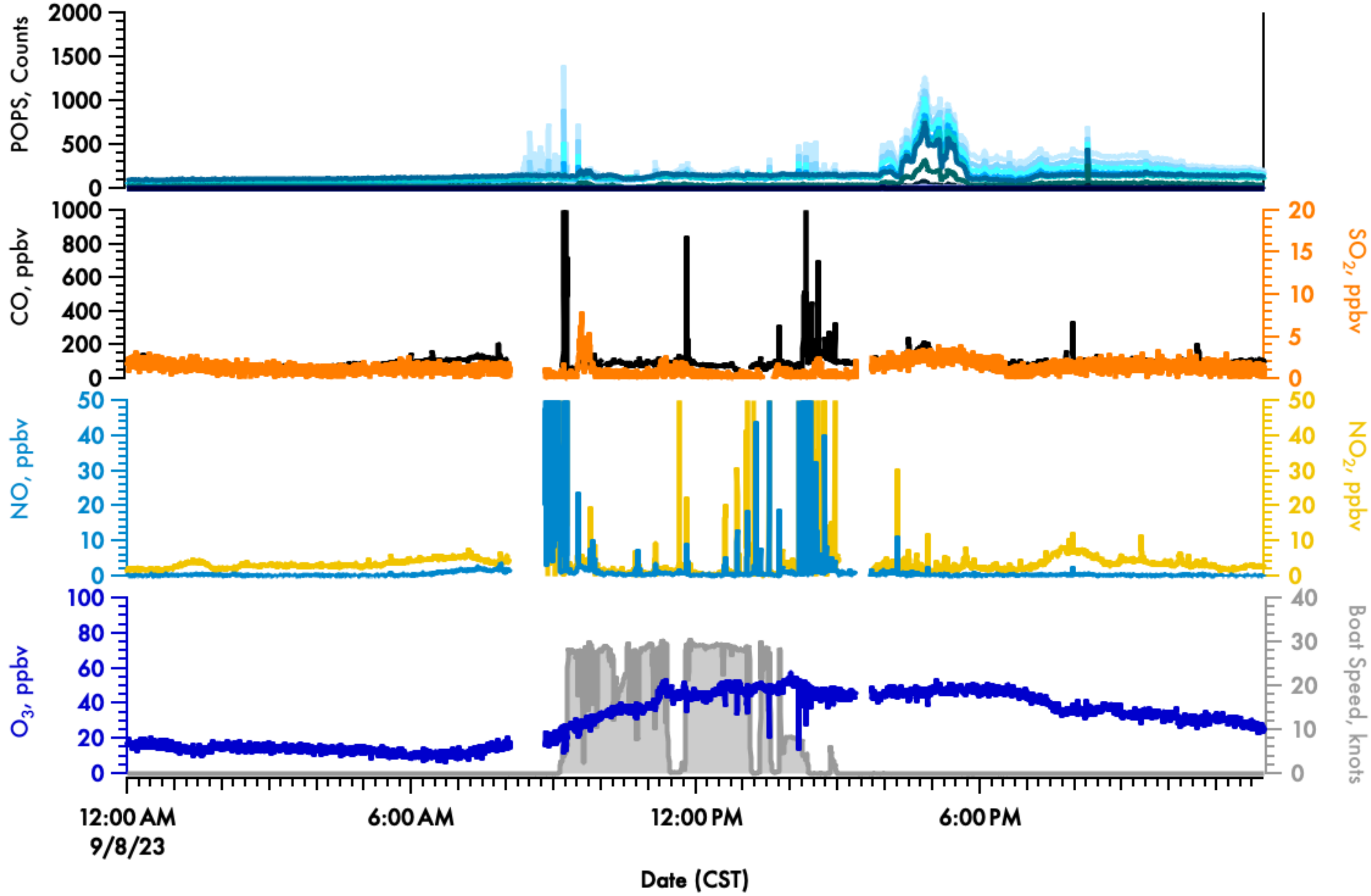

Figure 111. *Trace gases and POPS measurements collected from the MAQL-Sea boat platform on September 8, 2023.*

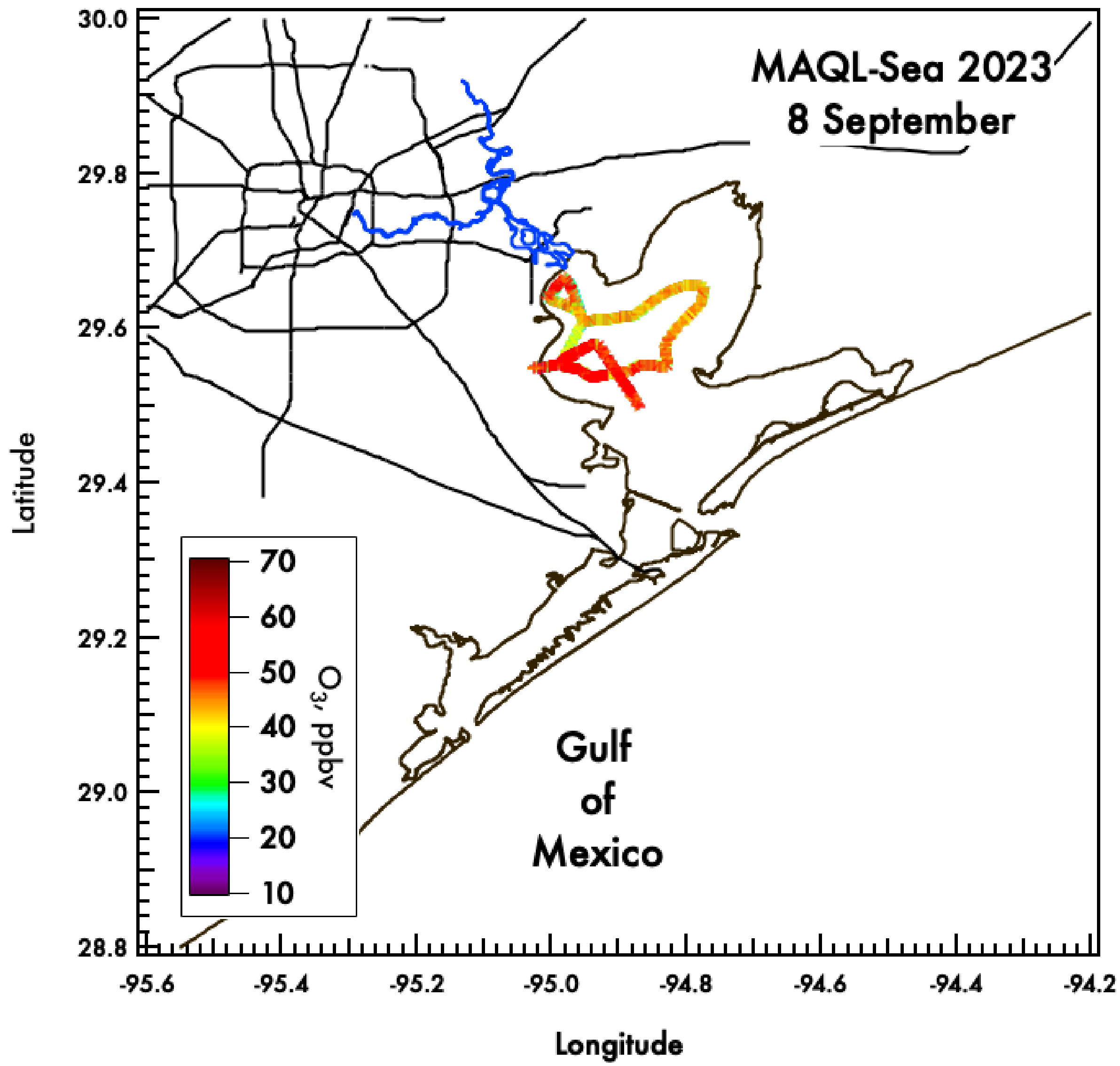

Figure 112. *Spatial plot of mobile measurement of ozone aboard MAQL-Sea boat platform on September 8, 2024*

September 10, 2023

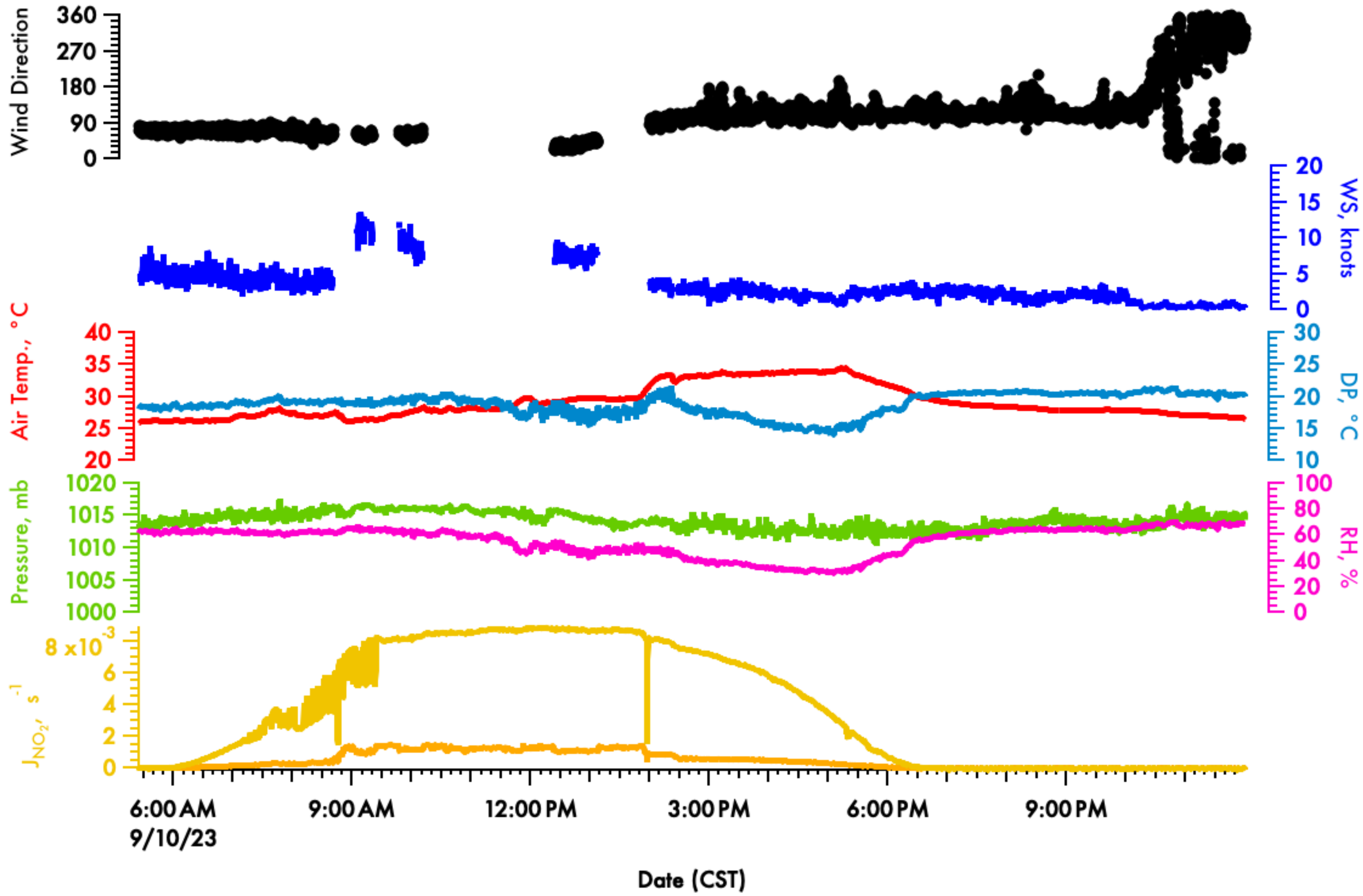

Figure 113. *Meteorological measurements collected from the MAQL-Sea boat platform on 10 September 2023.*

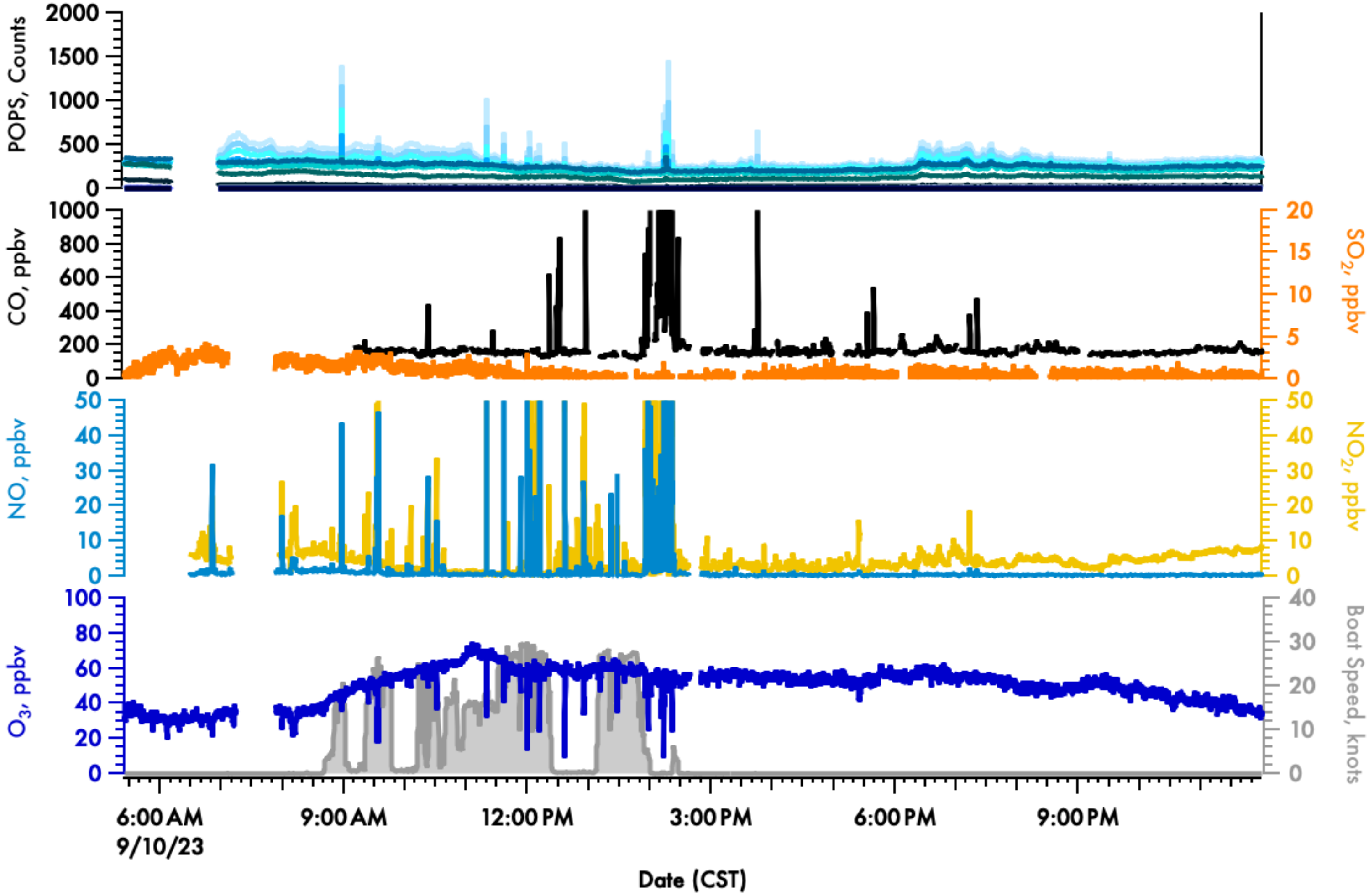

Figure 114. *Trace gases and POPS measurements collected from the MAQL-Sea boat platform on September 10, 2023.*

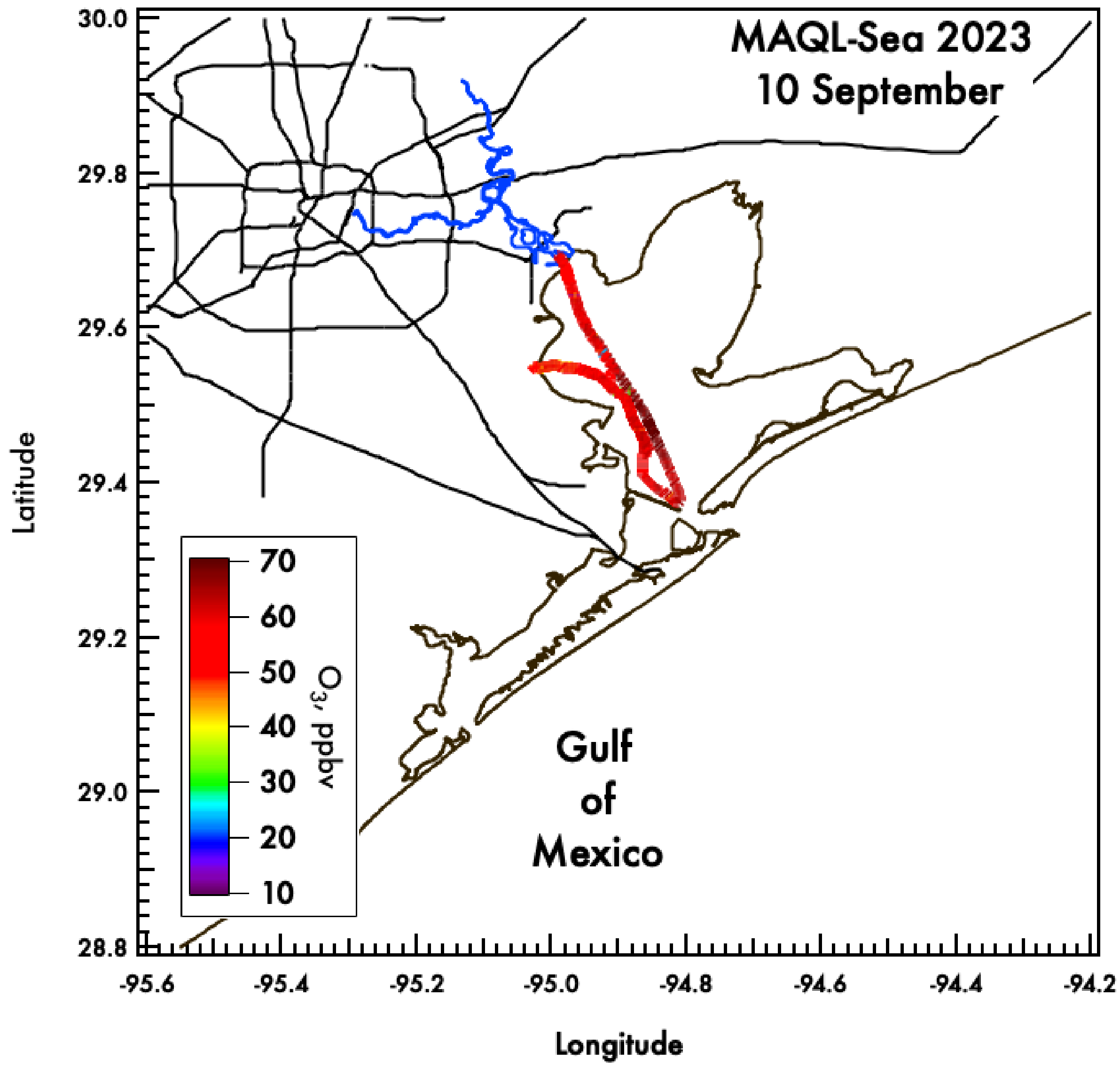

Figure 115. *Spatial plot of mobile measurement of ozone aboard MAQL-Sea boat platform on September 10, 2024*

September 11, 2023

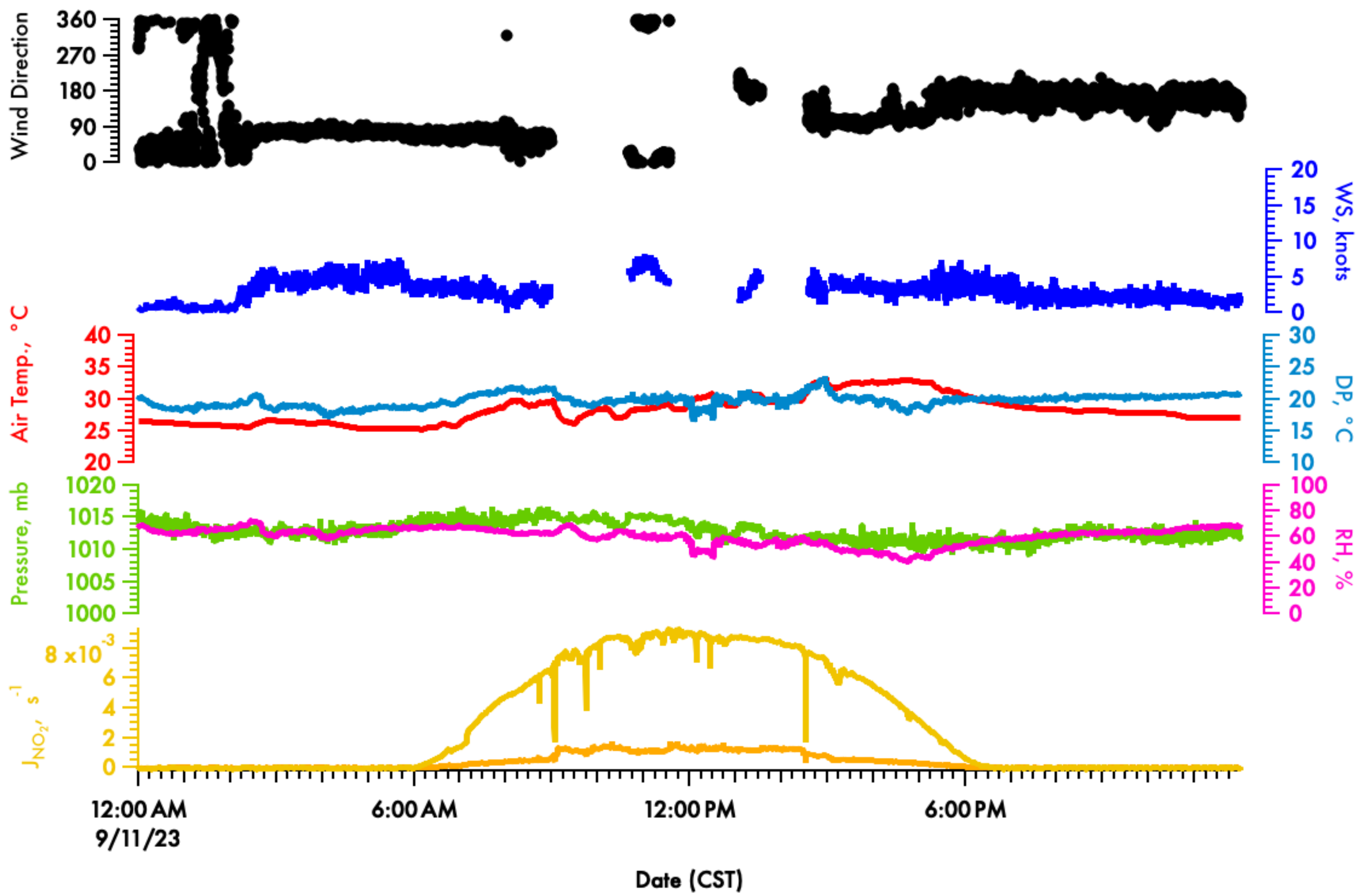

Figure 116. *Meteorological measurements collected from the MAQL-Sea boat platform on 11 September 2023.*

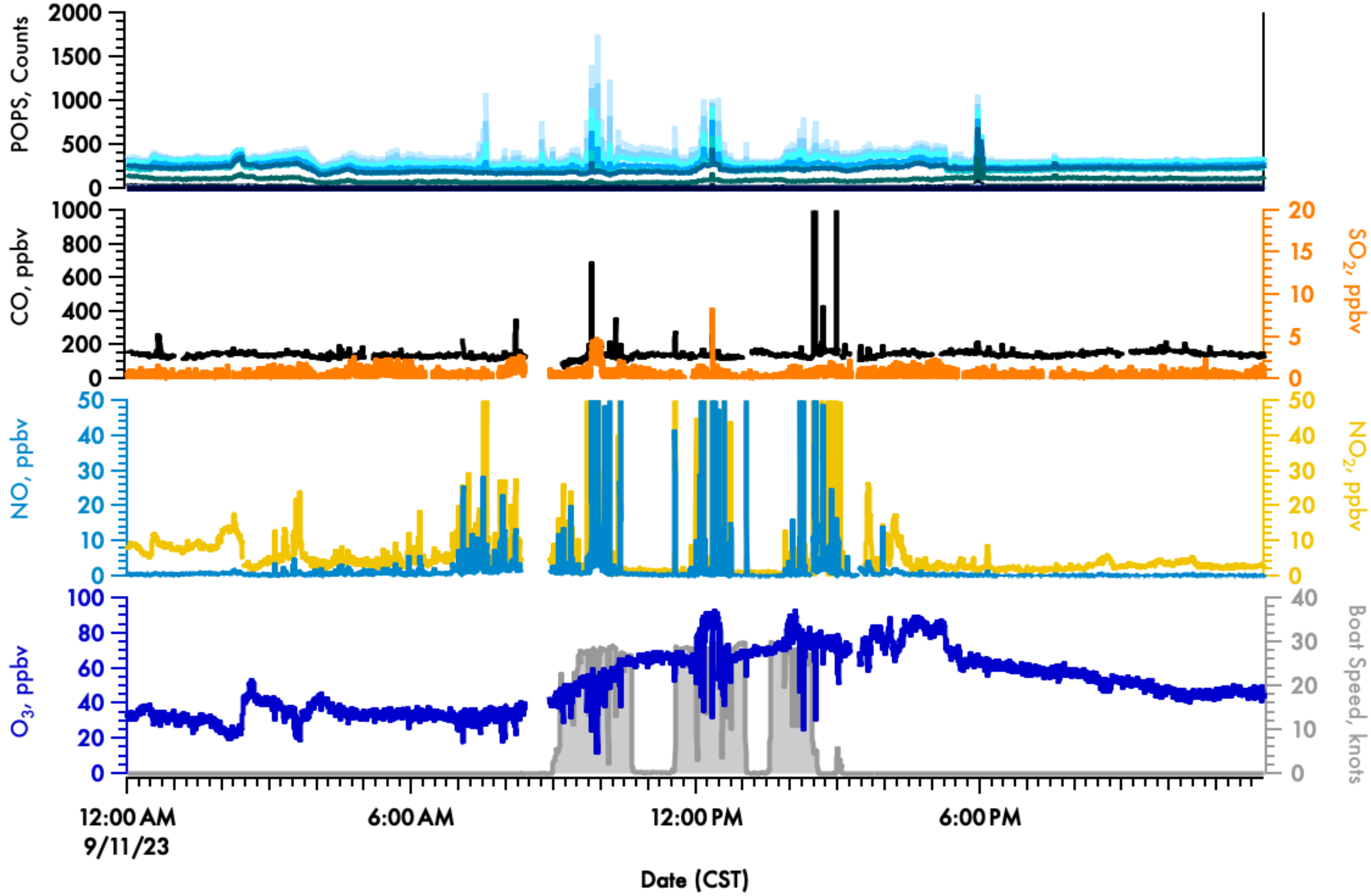

Figure 117. *Trace gases and POPS measurements collected from the MAQL-Sea boat platform on September 11, 2023.*

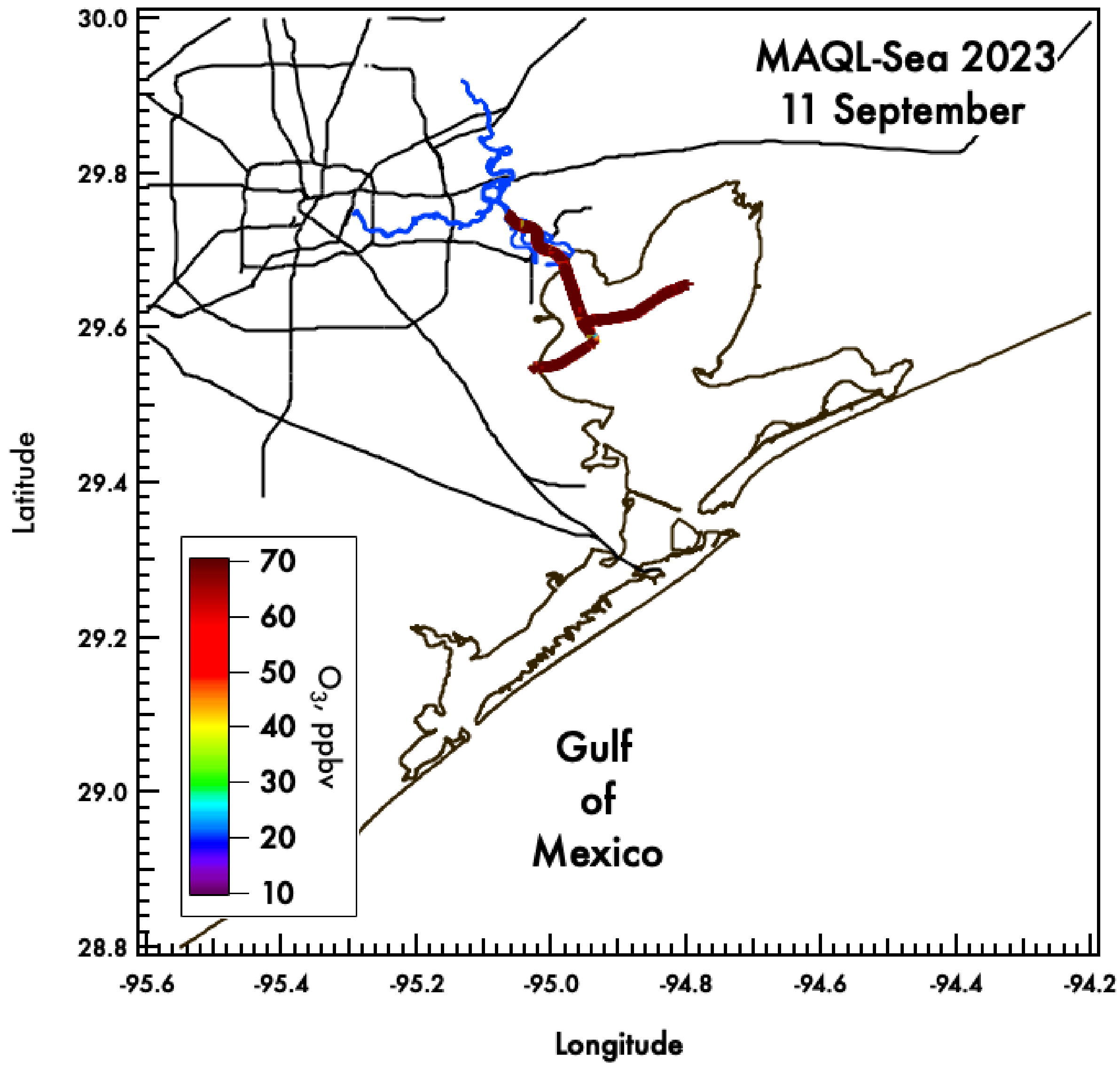

Figure 118. *Spatial plot of mobile measurement of ozone aboard MAQL-Sea boat platform on September 11, 2024*

September 13, 2023

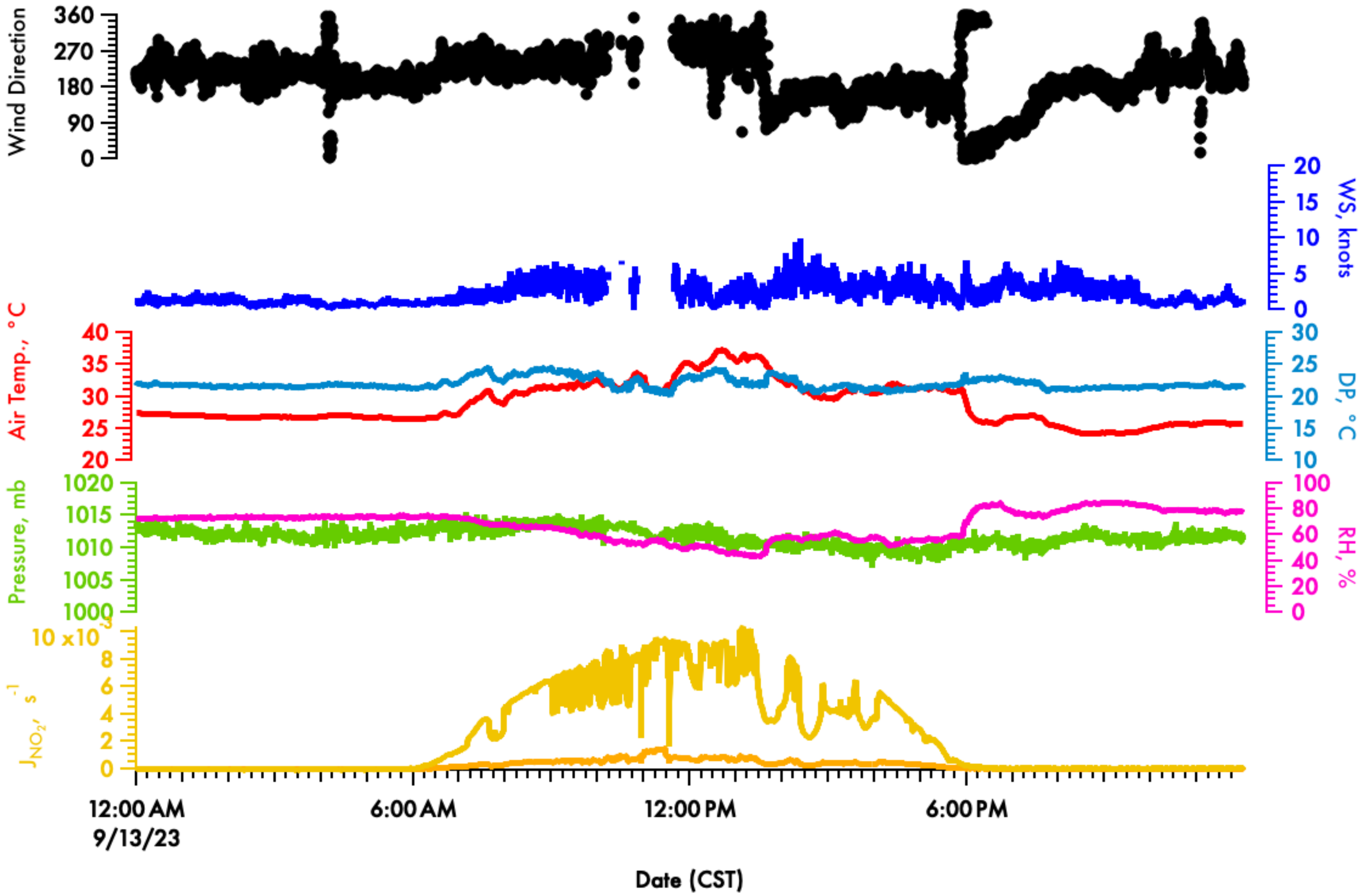

Figure 119. *Meteorological measurements collected from the MAQL-Sea boat platform on 13 September 2023.*

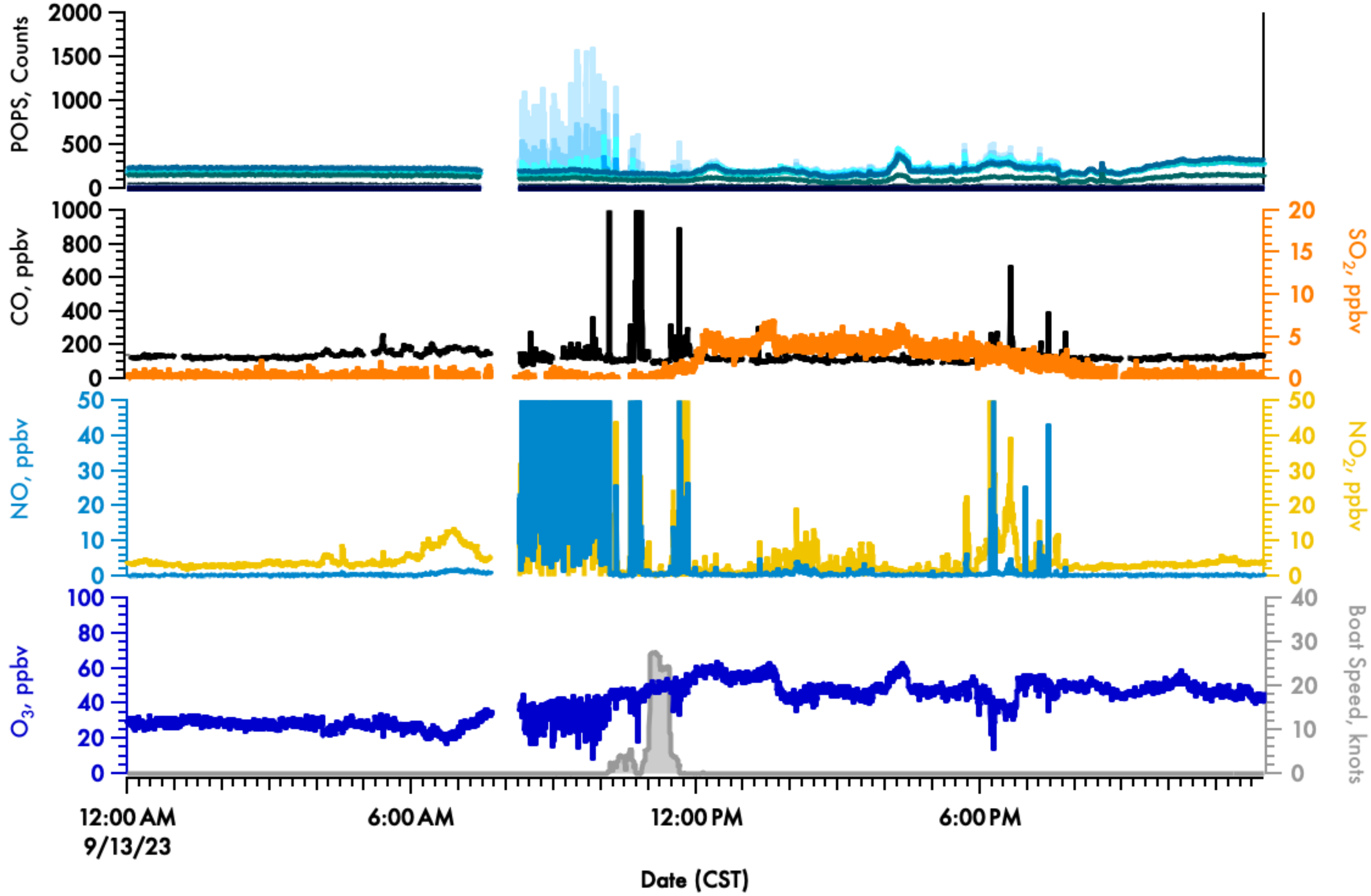

Figure 120. *Trace gases and POPS measurements collected from the MAQL-Sea boat platform on September 13, 2023.*

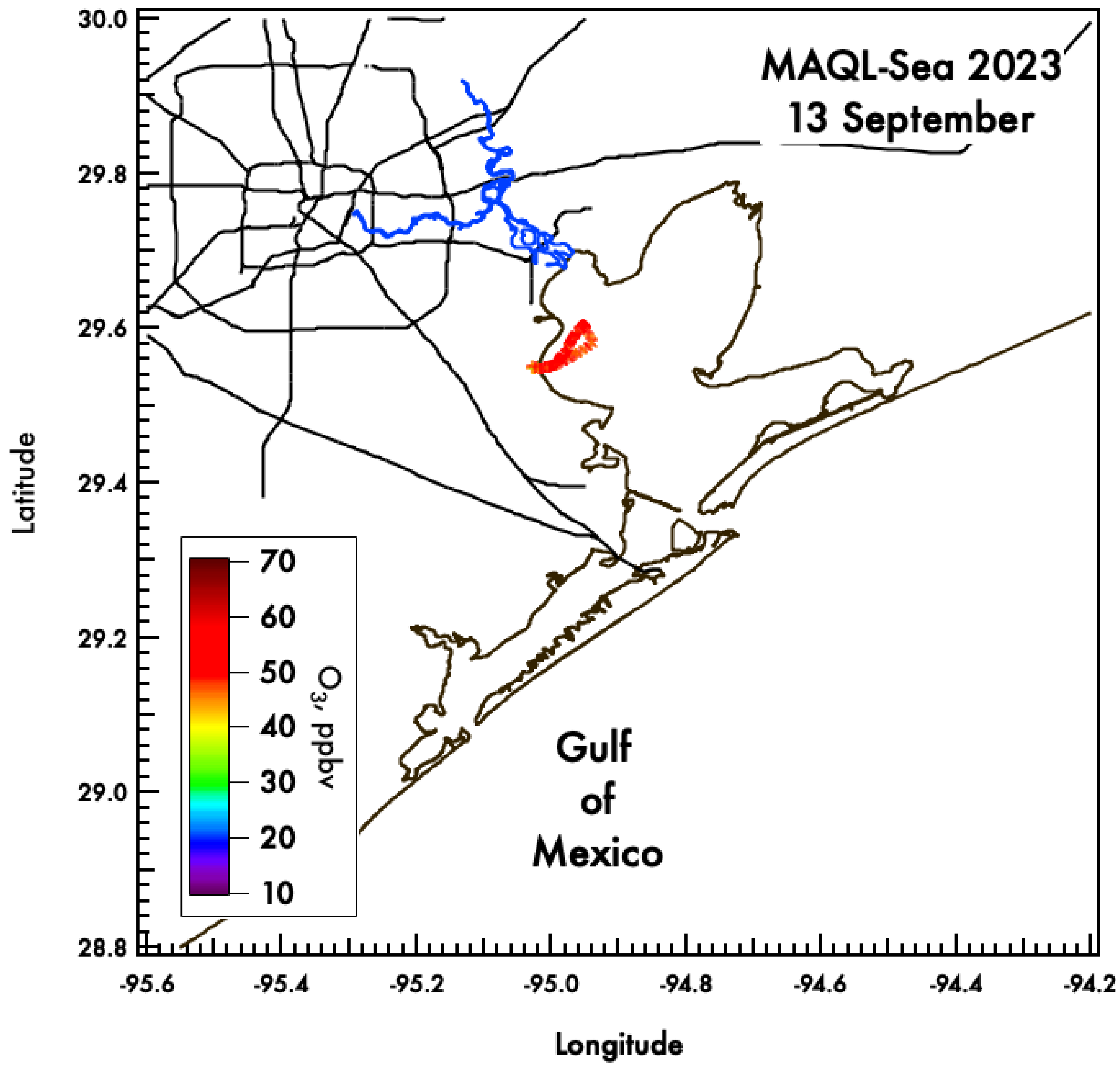

Figure 121. *Spatial plot of mobile measurement of ozone aboard MAQL-Sea boat platform on September 13, 2024*

September 17, 2023

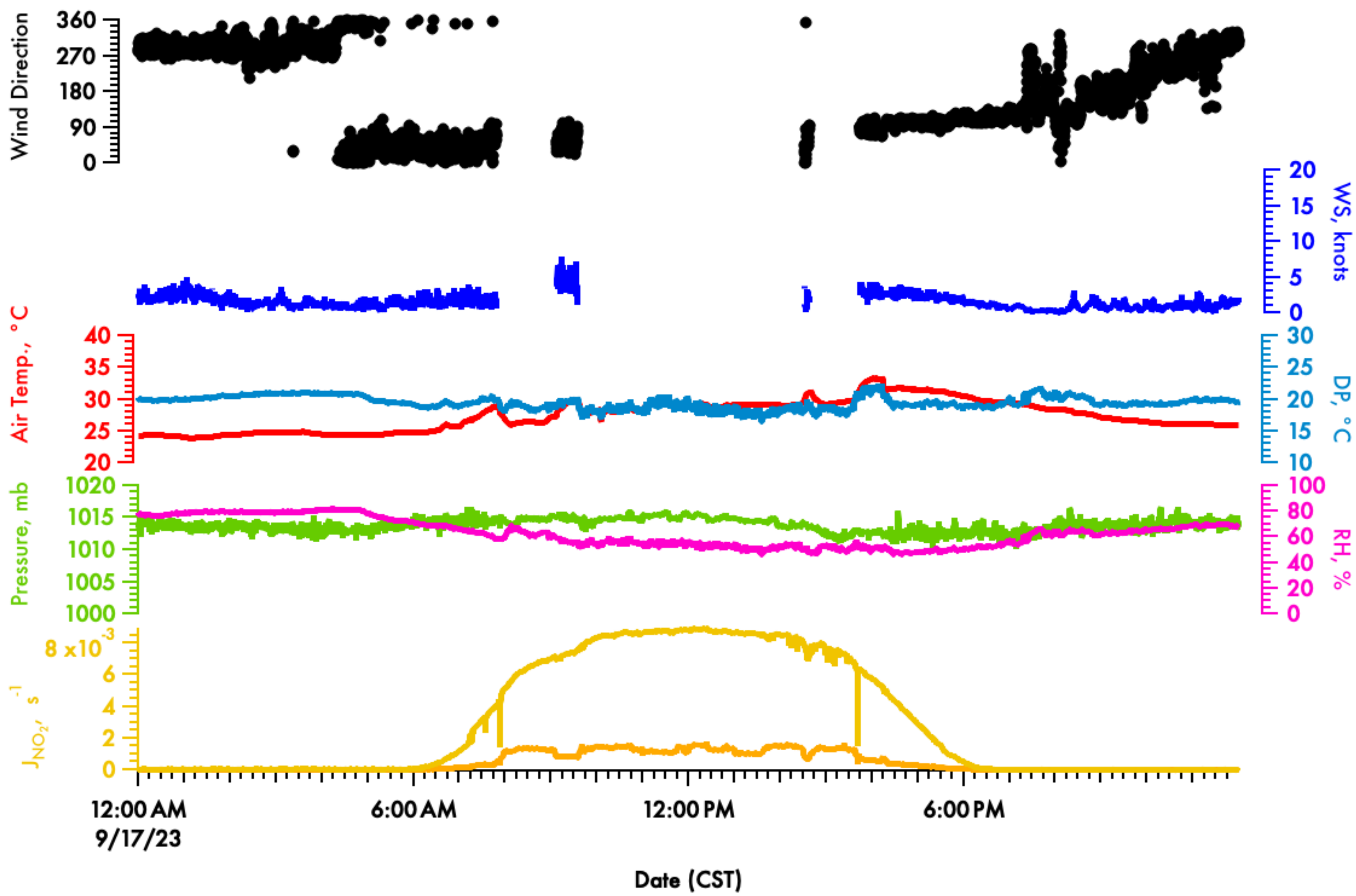

Figure 122. *Meteorological measurements collected from the MAQL-Sea boat platform on 17 September 2023.*

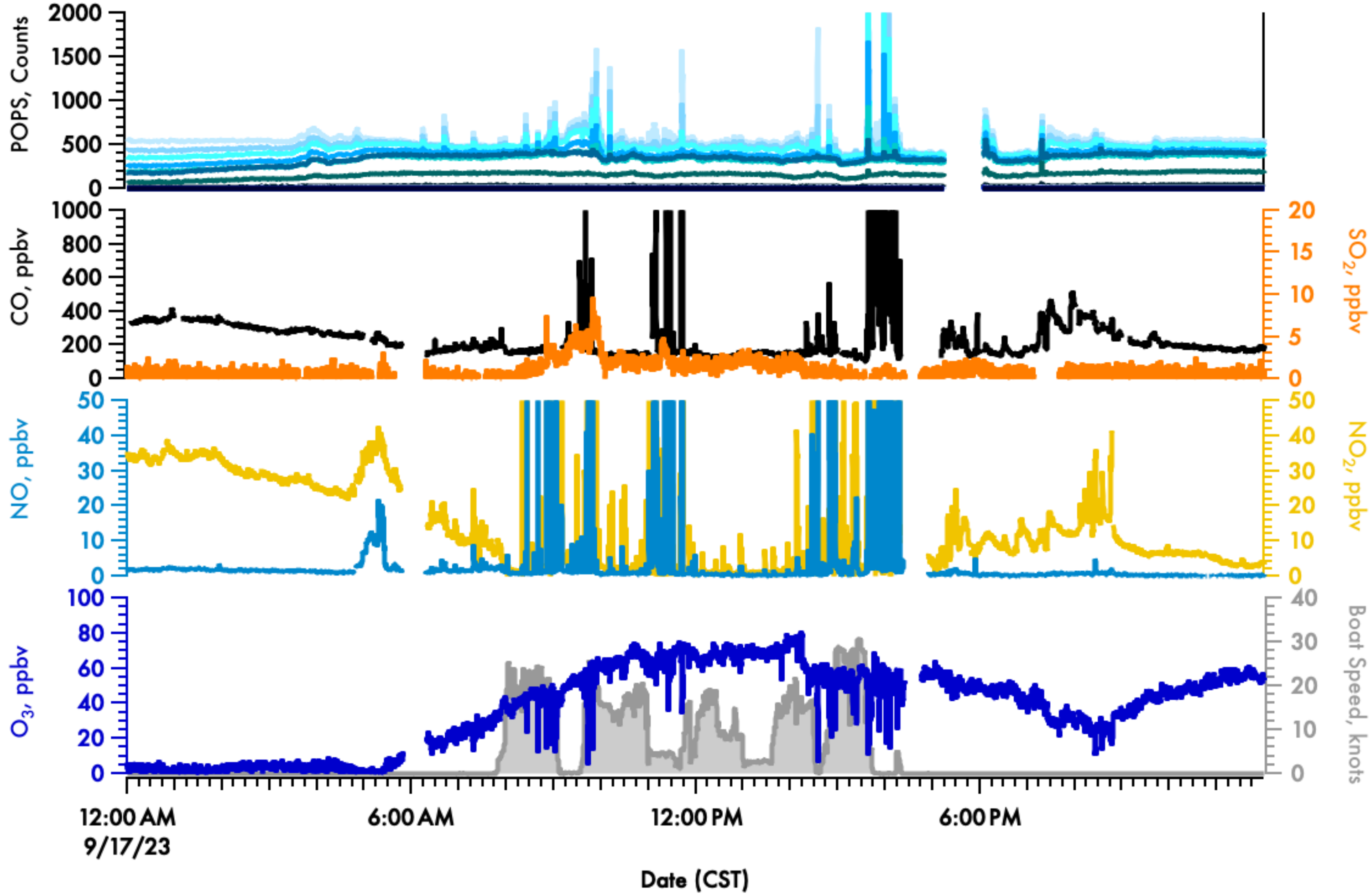

Figure 123. *Trace gases and POPS measurements collected from the MAQL-Sea boat platform on September 17, 2023.*

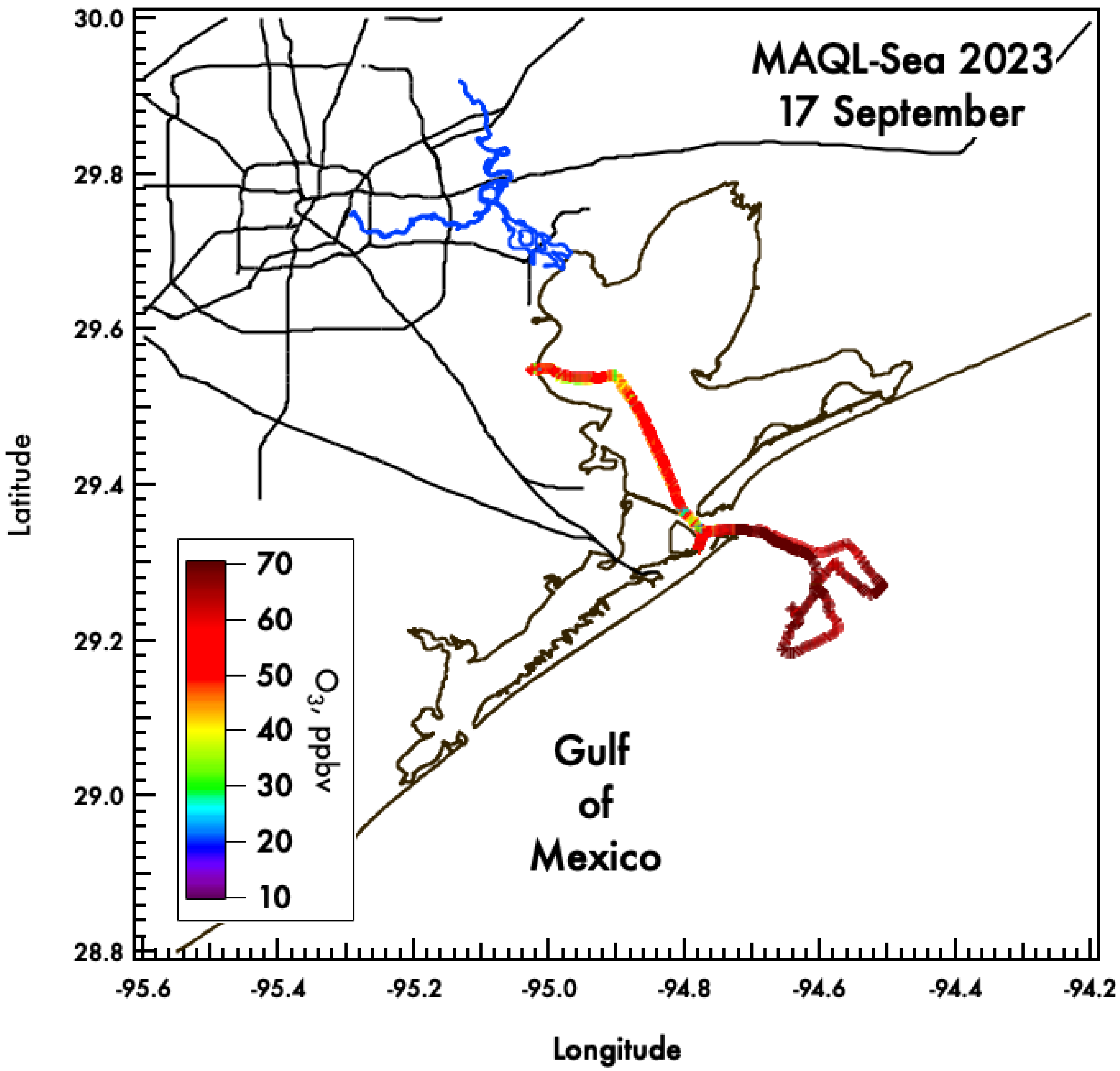

Figure 124. *Spatial plot of mobile measurement of ozone aboard MAQL-Sea boat platform on September 17, 2024*

September 18, 2023

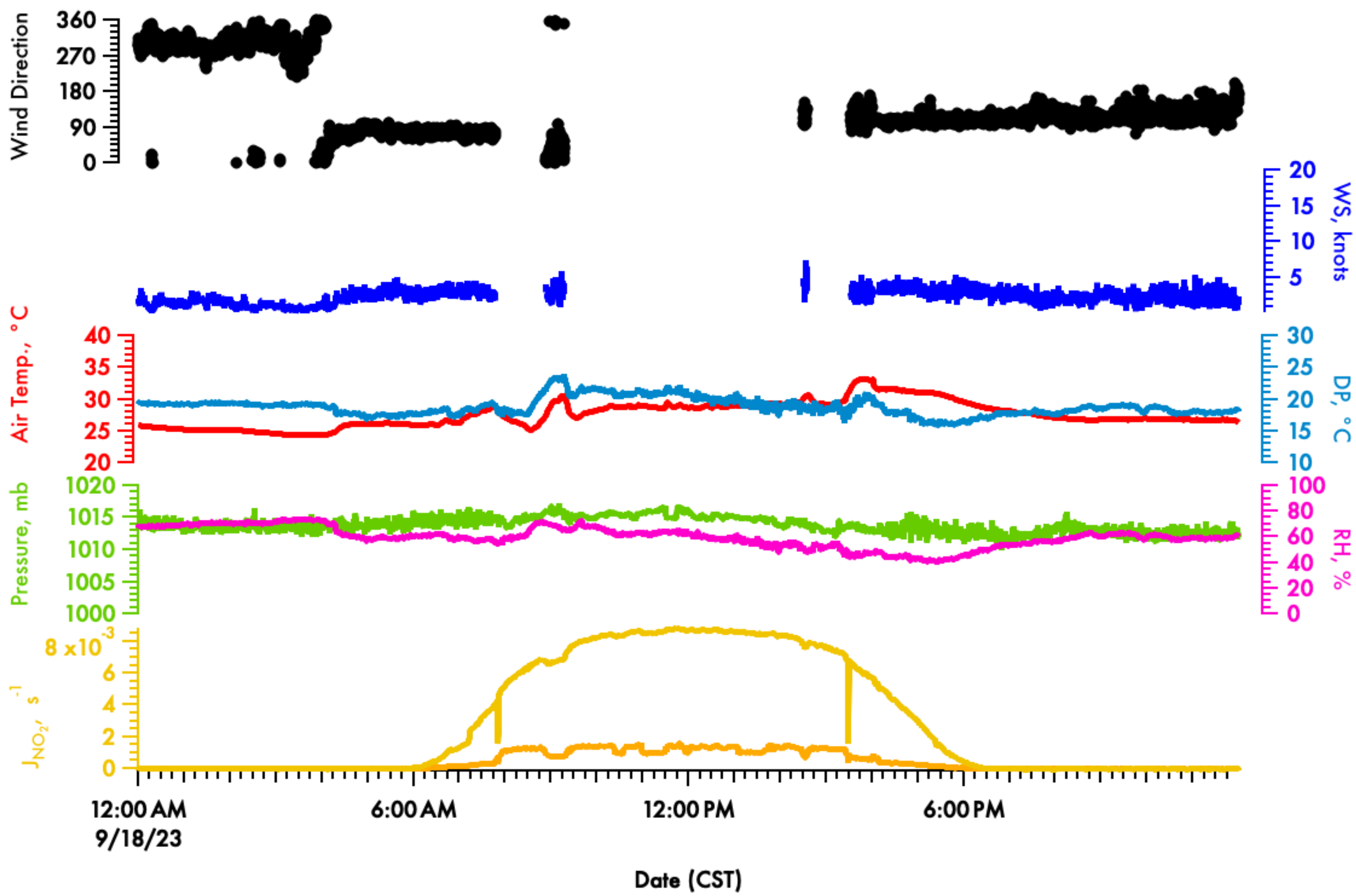

Figure 125. *Meteorological measurements collected from the MAQL-Sea boat platform on 18 September 2023.*

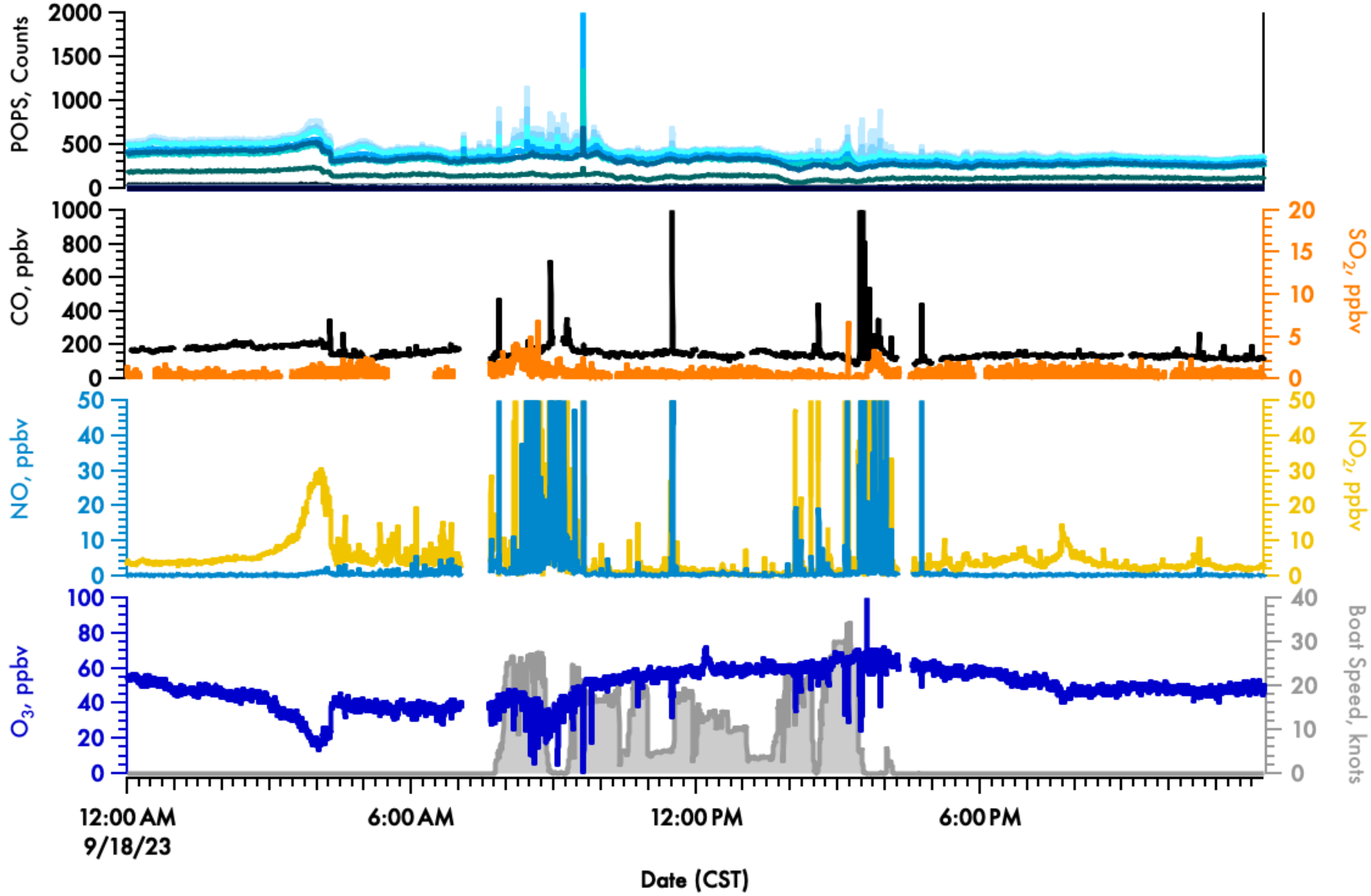

Figure 126. *Trace gases and POPS measurements collected from the MAQL-Sea boat platform on September 18, 2023.*

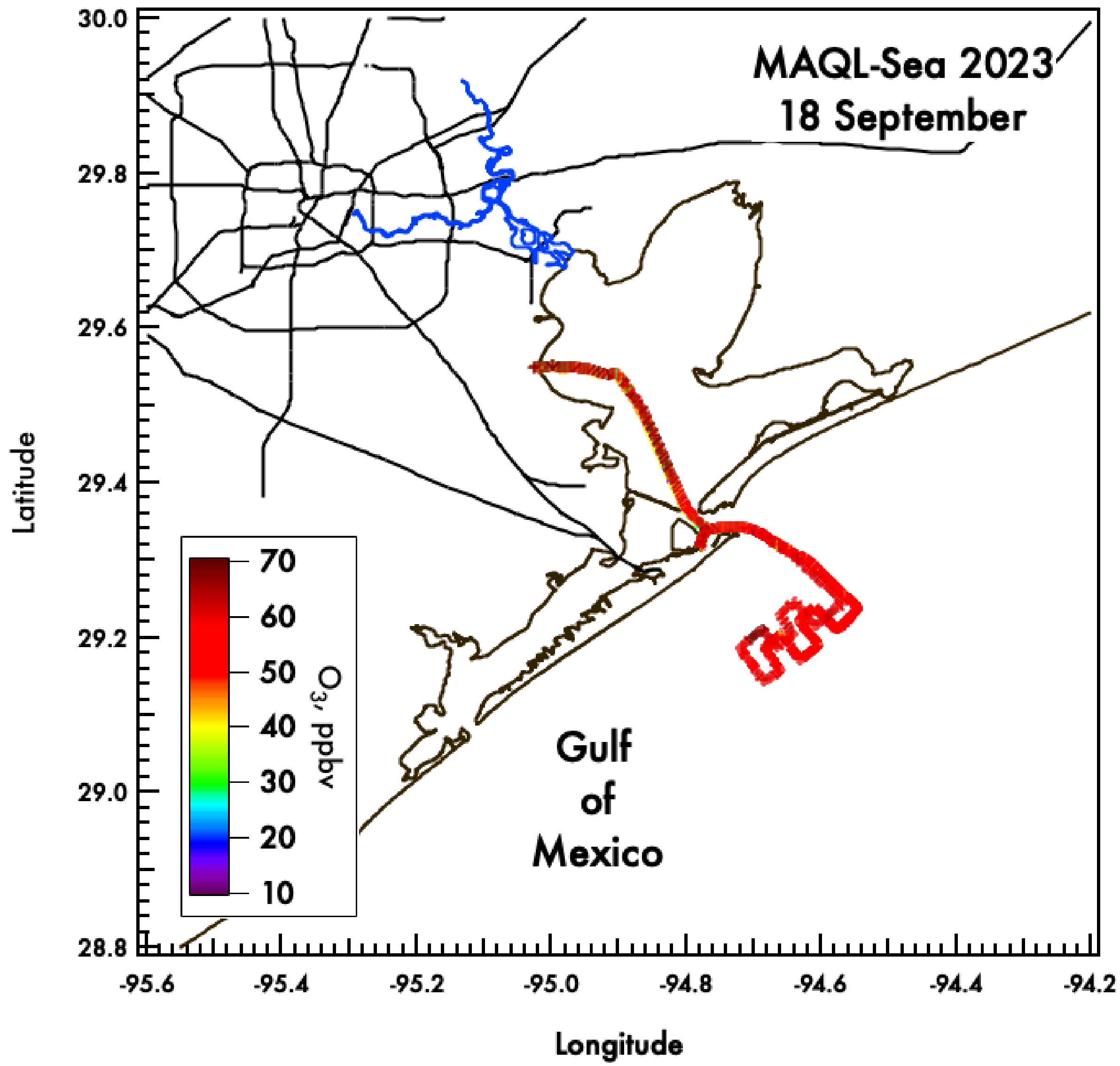

Figure 127. *Spatial plot of mobile measurement of ozone aboard MAQL-Sea boat platform on September 18, 2024*

September 19, 2023

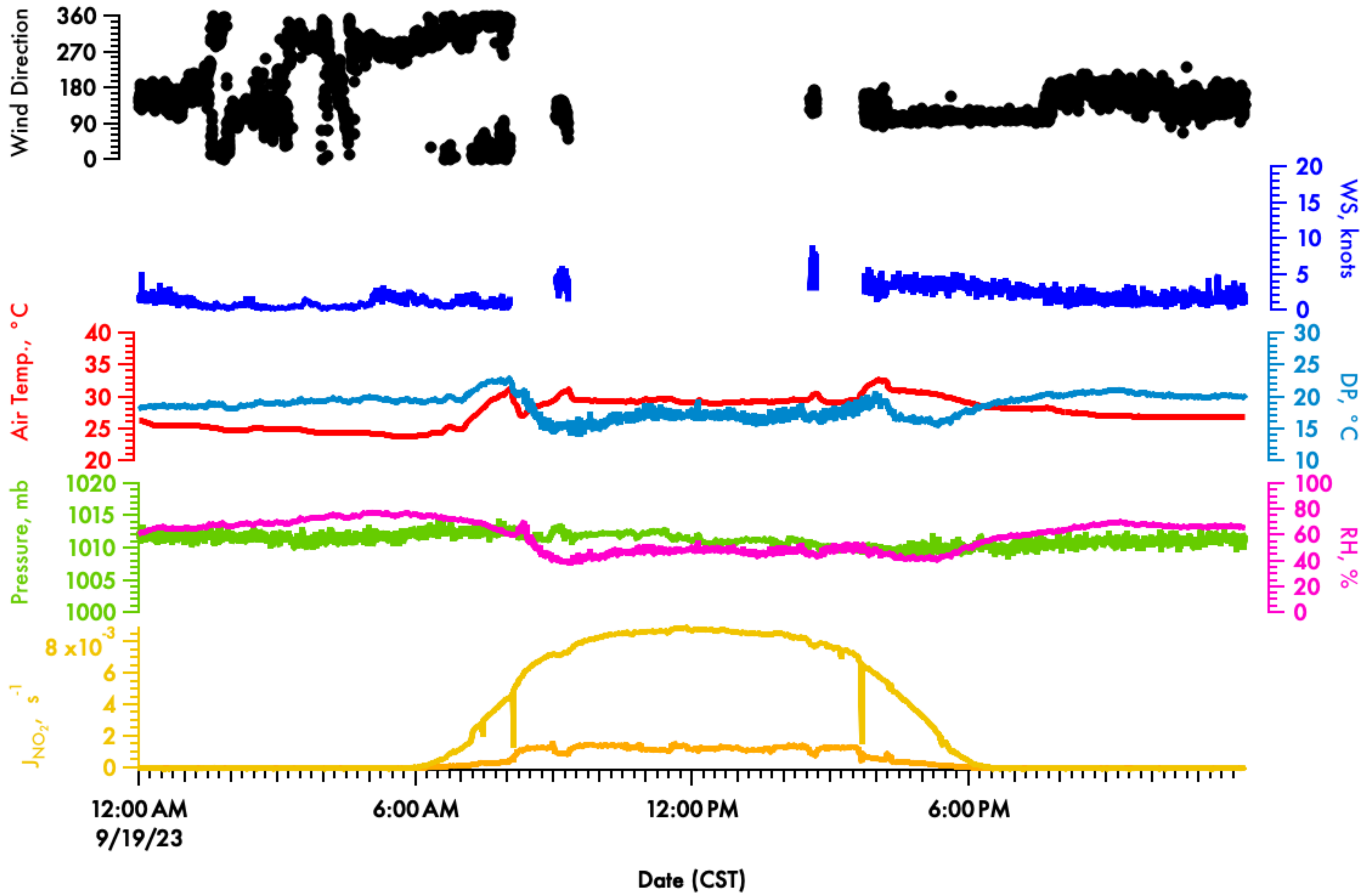

Figure 128. *Meteorological measurements collected from the MAQL-Sea boat platform on 19 September 2023.*

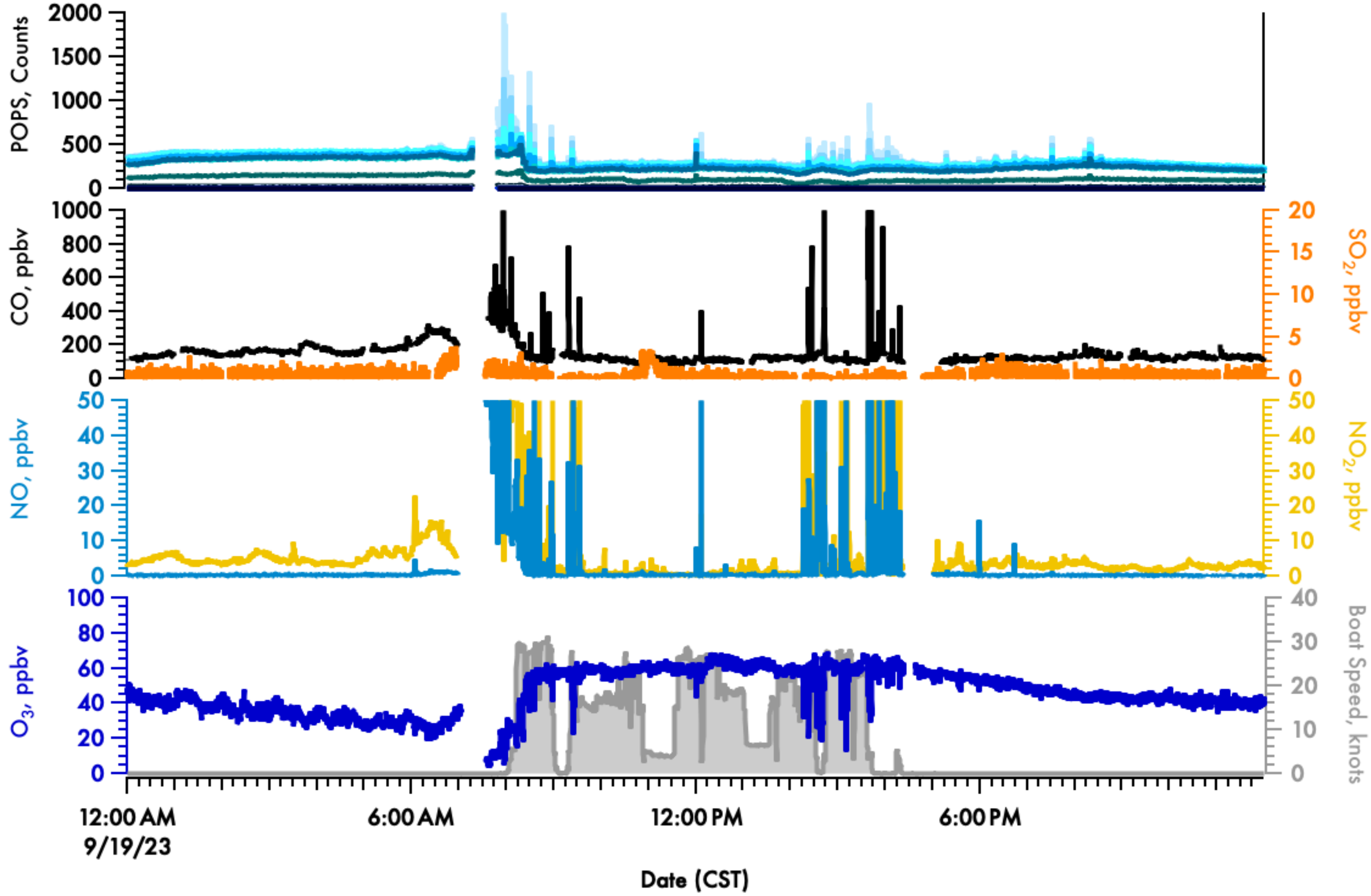

Figure 129. *Trace gases and POPS measurements collected from the MAQL-Sea boat platform on September 19, 2023.*

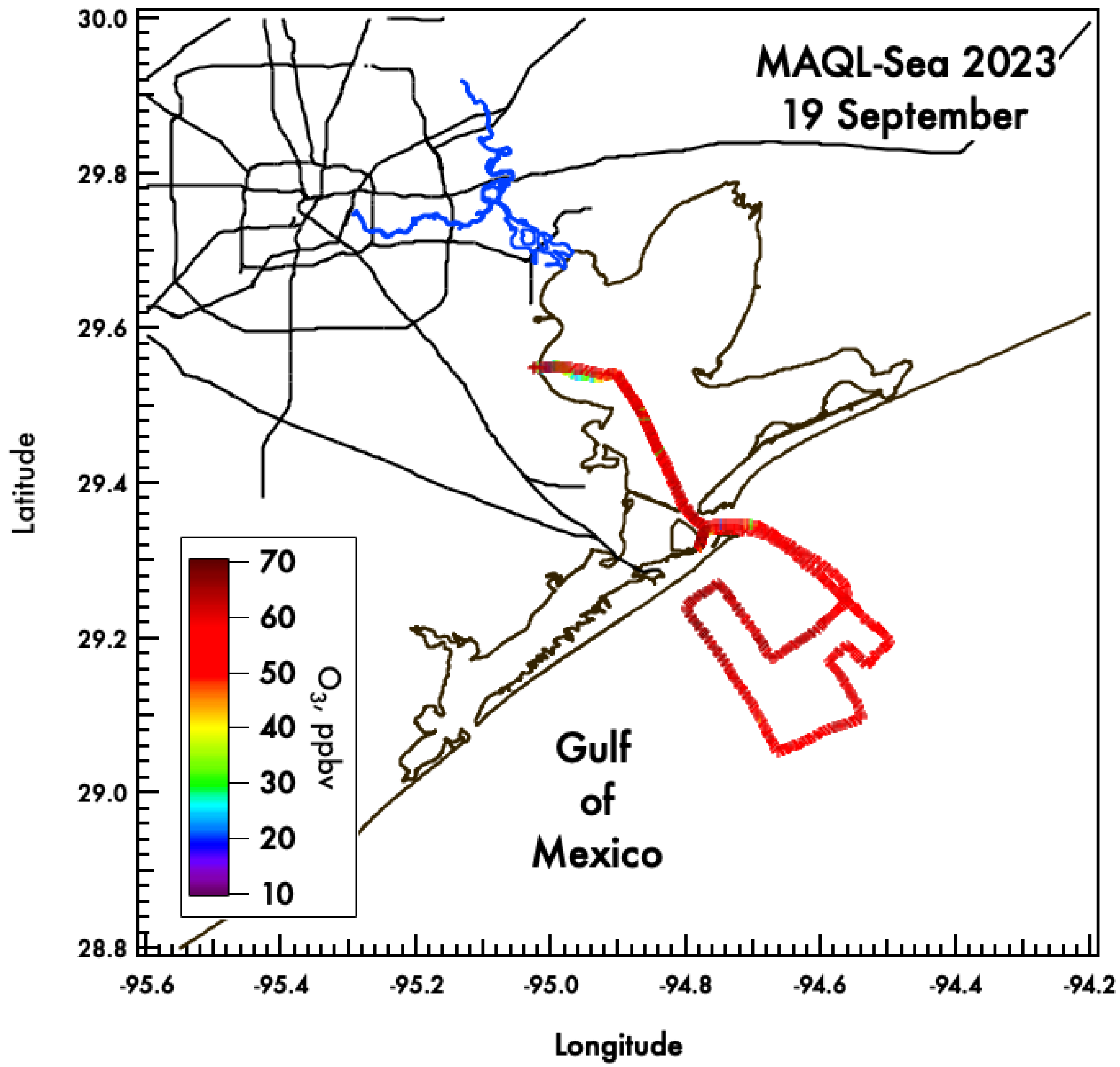

Figure 130. *Spatial plot of mobile measurement of ozone aboard MAQL-Sea boat platform on September 19, 2024*

September 21, 2023

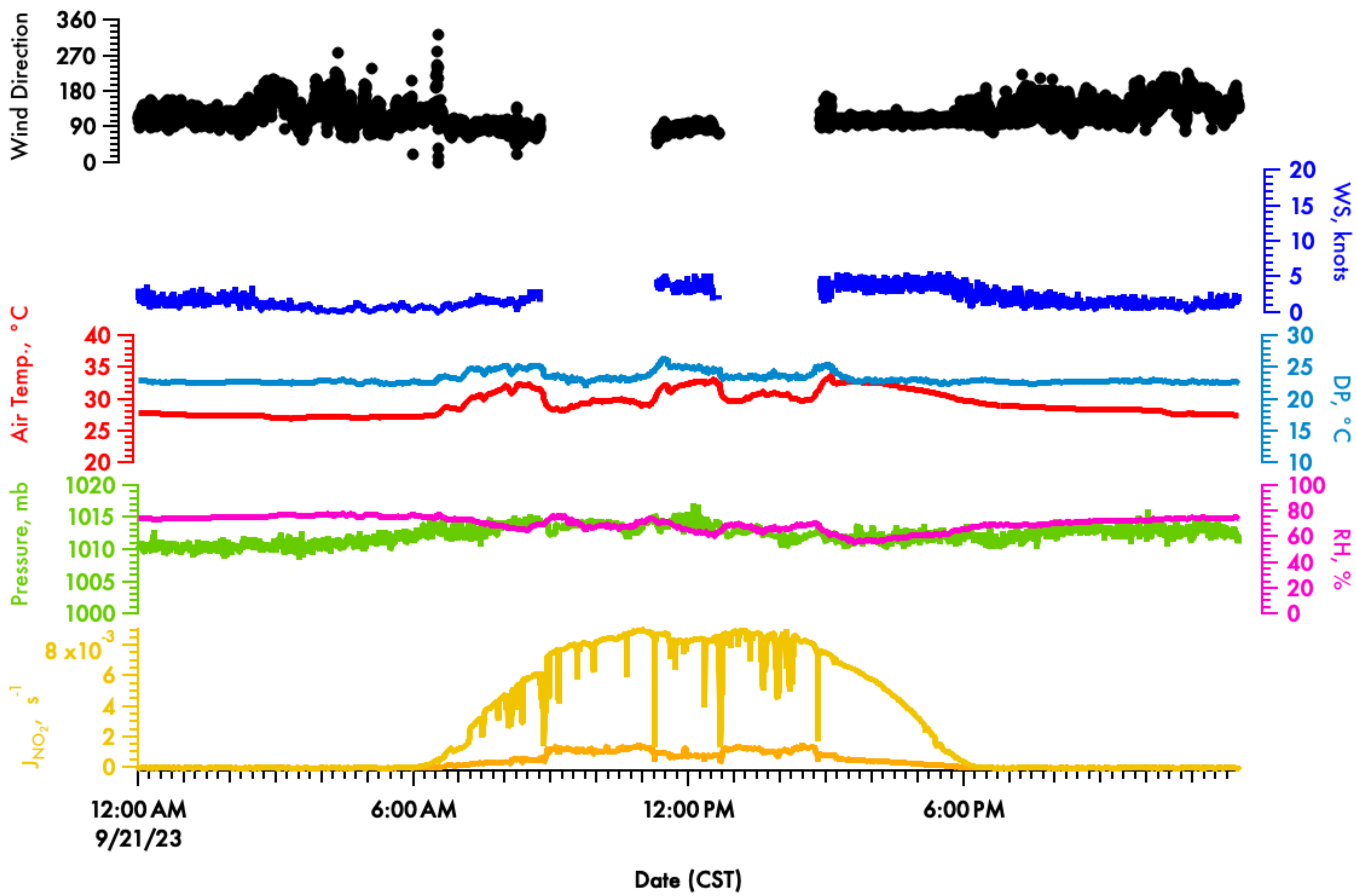

Figure 131. *Meteorological measurements collected from the MAQL-Sea boat platform on 21 September 2023.*

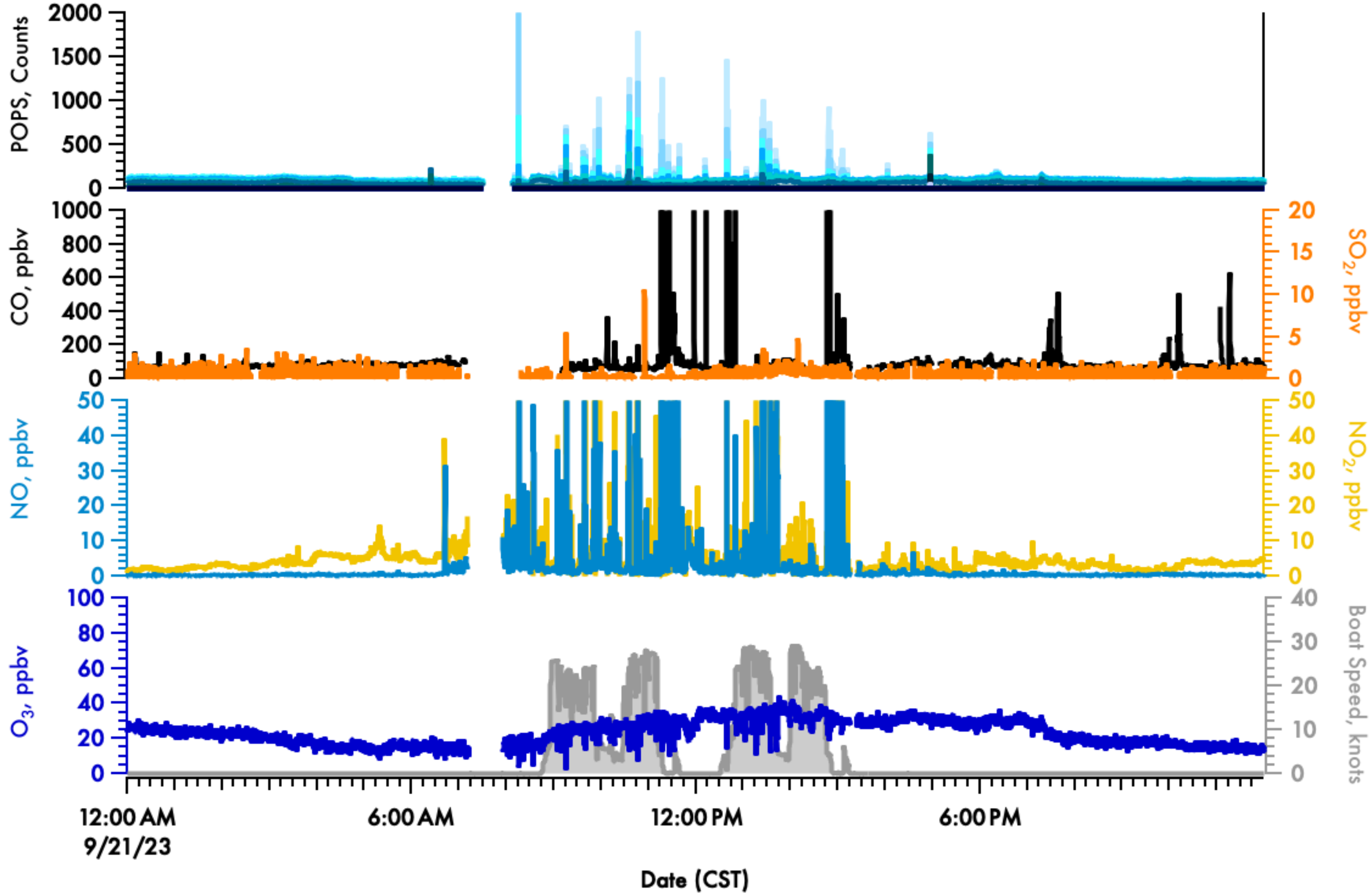

Figure 132. *Trace gases and POPS measurements collected from the MAQL-Sea boat platform on September 21, 2023.*

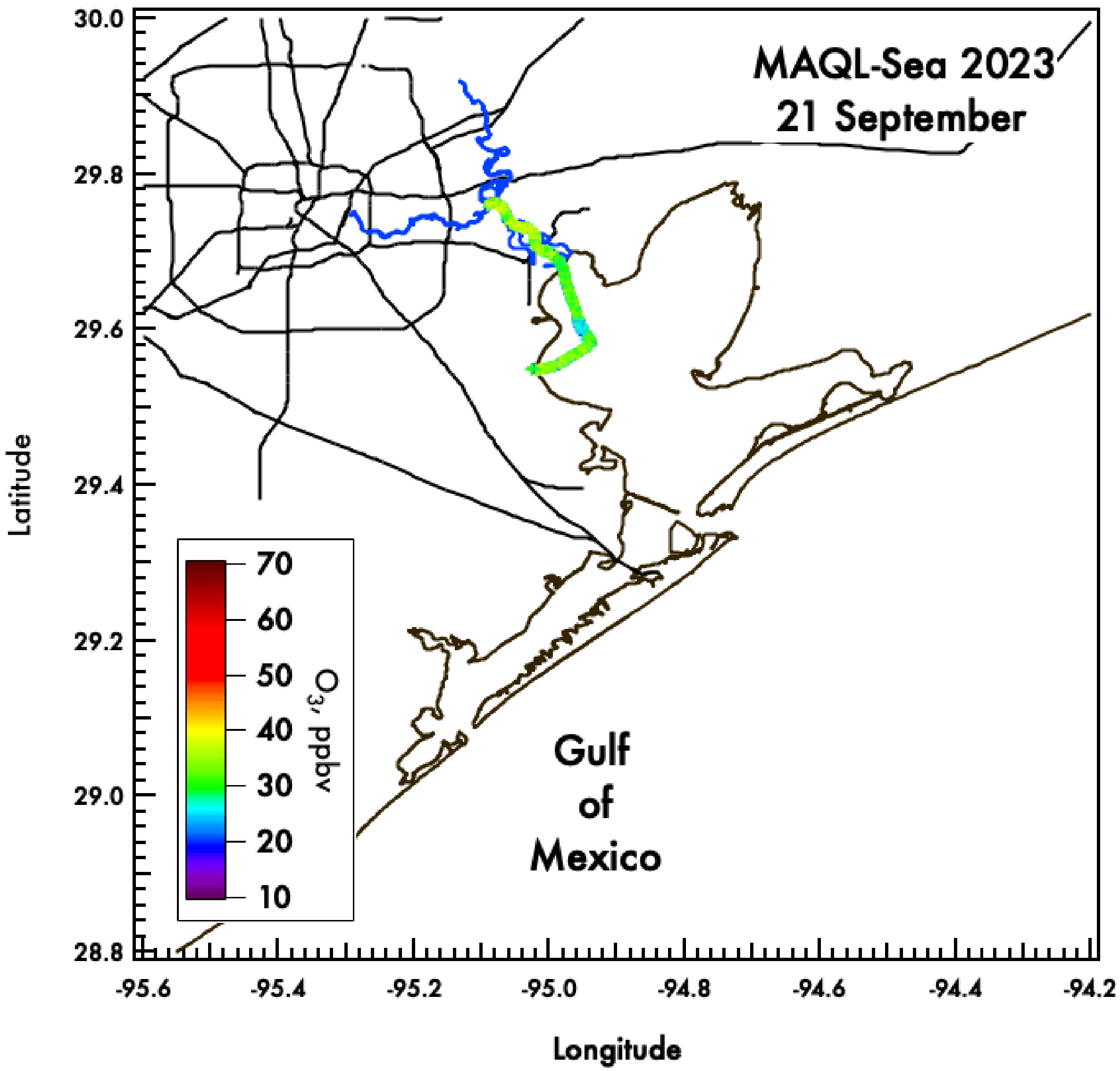

Figure 133. *Spatial plot of mobile measurement of ozone aboard MAQL-Sea boat platform on September 21, 2024*

September 22, 2023

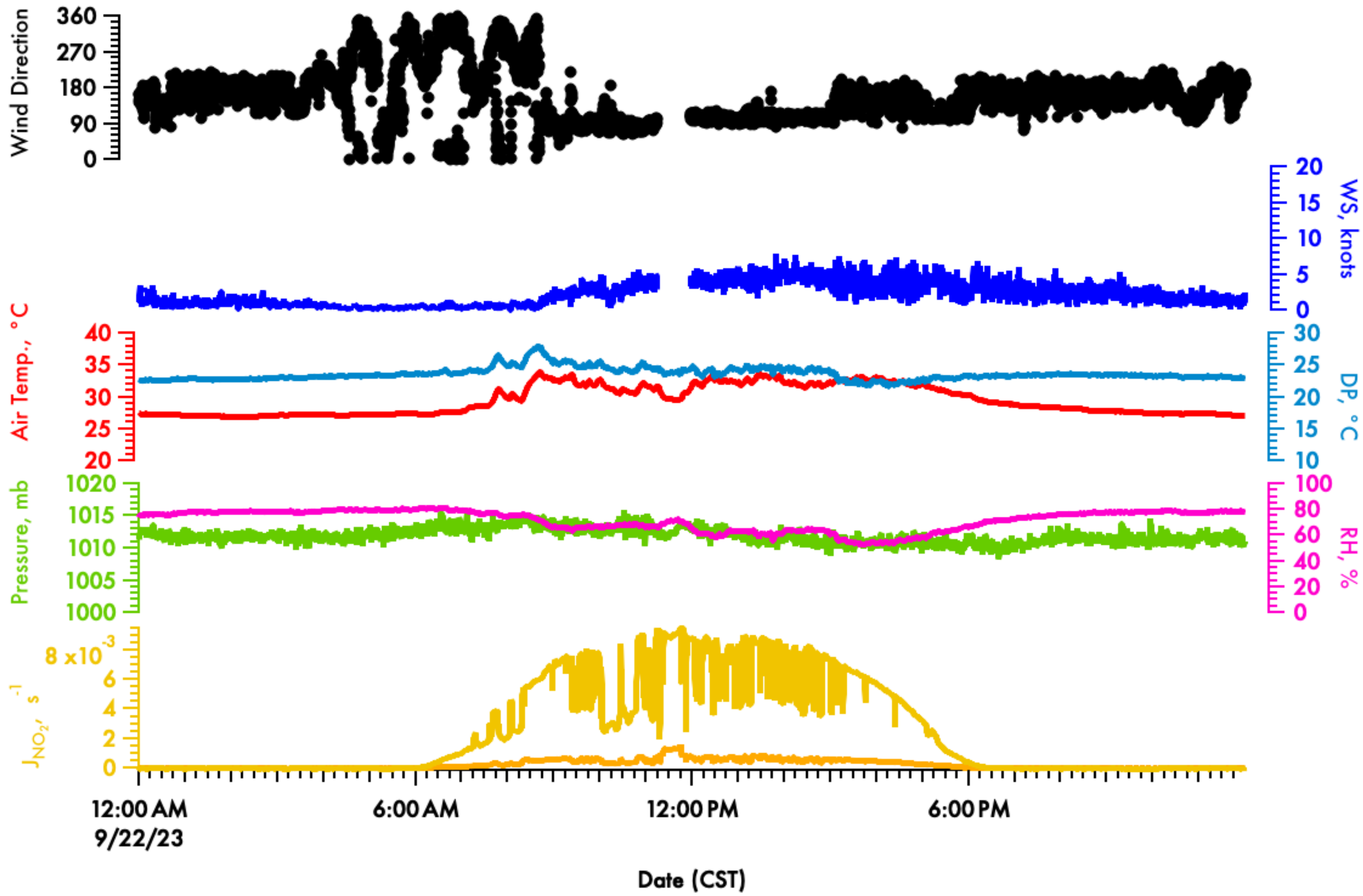

Figure 134. *Meteorological measurements collected from the MAQL-Sea boat platform on 22 September 2023.*

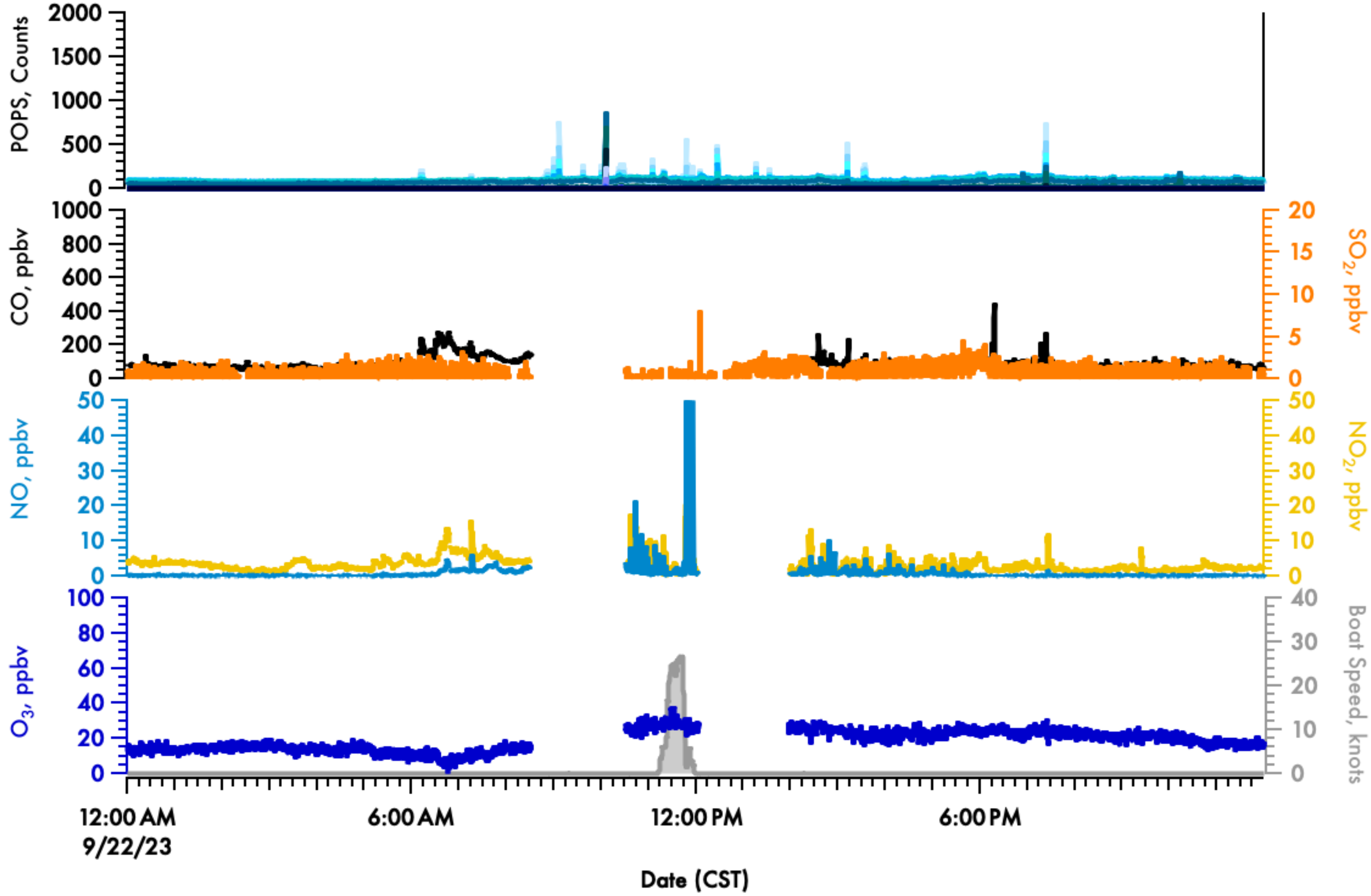

Figure 135. *Trace gases and POPS measurements collected from the MAQL-Sea boat platform on September 22, 2023.*

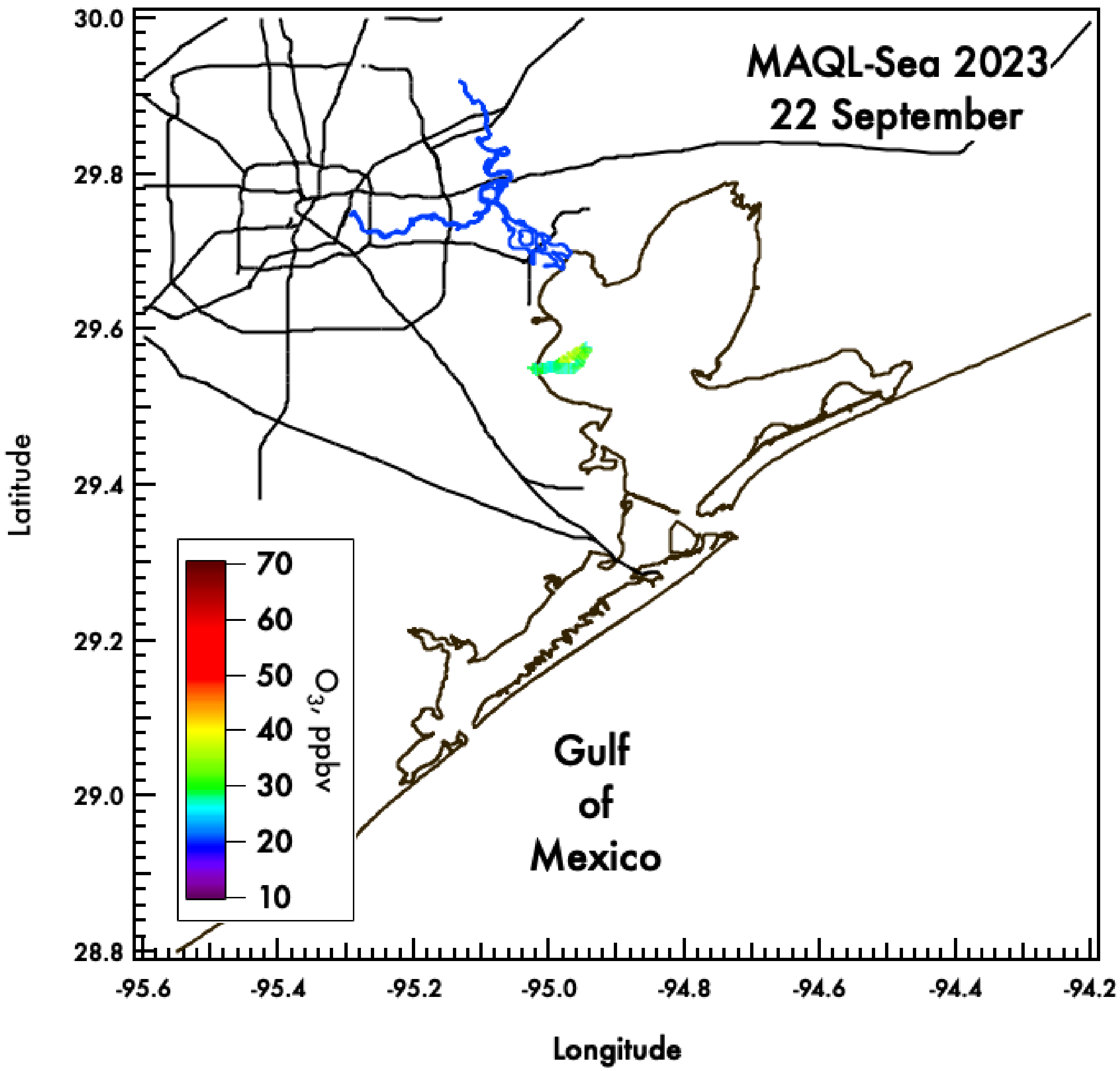

Figure 136. *Spatial plot of mobile measurement of ozone aboard MAQL-Sea boat platform on September 22, 2024.*

September 24, 2023

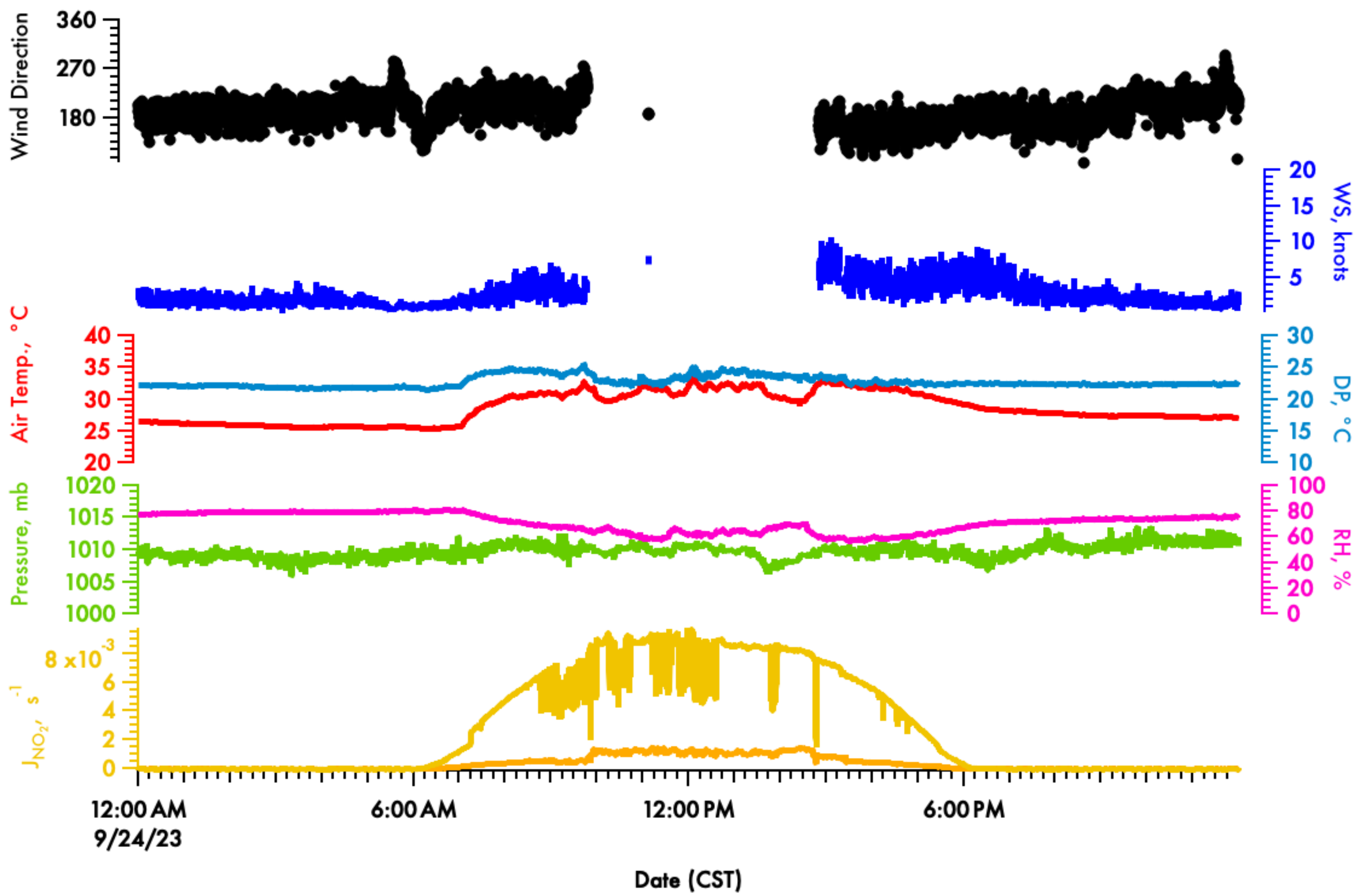

Figure 137. *Meteorological measurements collected from the MAQL-Sea boat platform on 24 September 2023.*

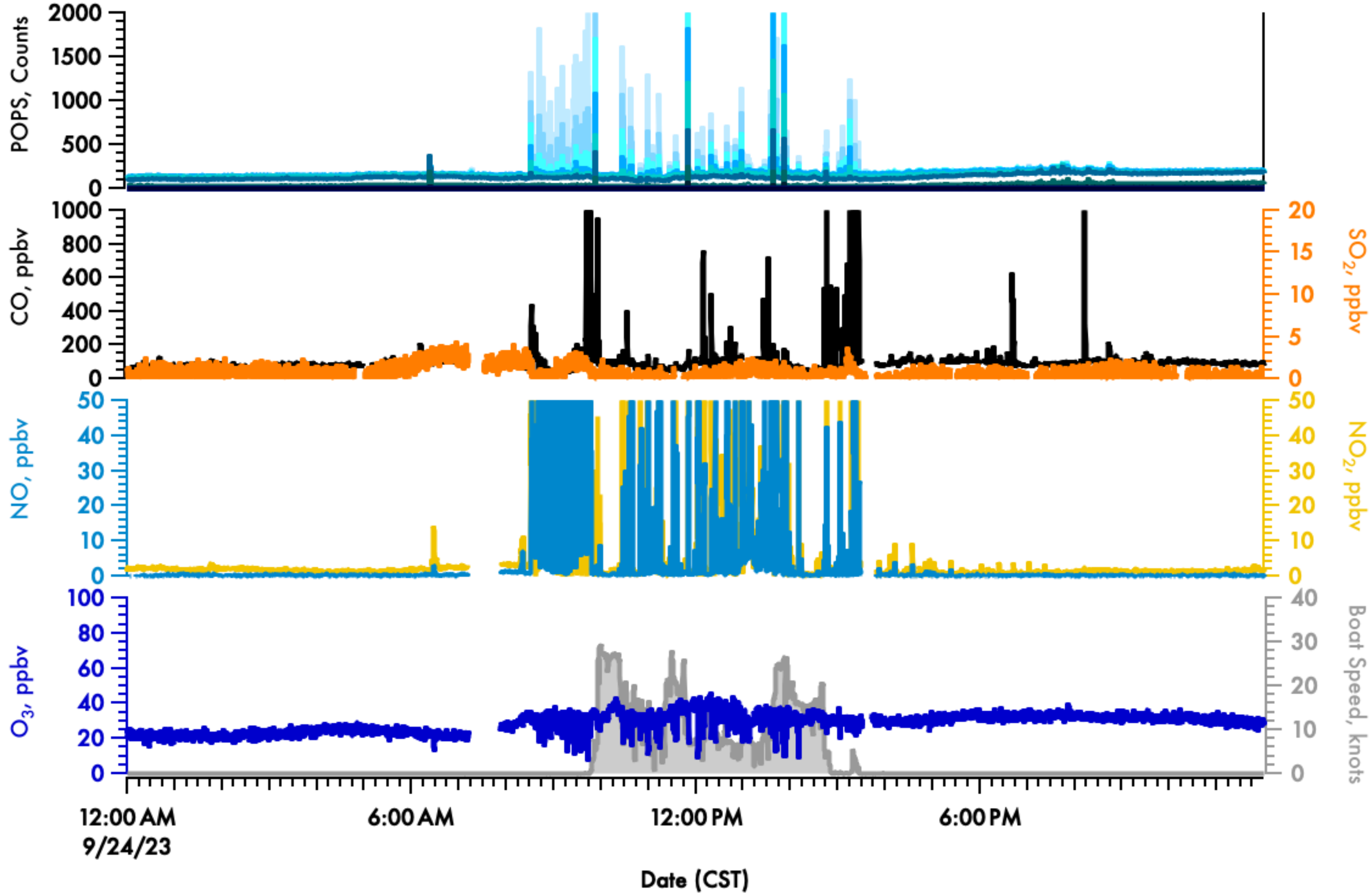

Figure 138. *Trace gases and POPS measurements collected from the MAQL-Sea boat platform on September 24, 2023.*

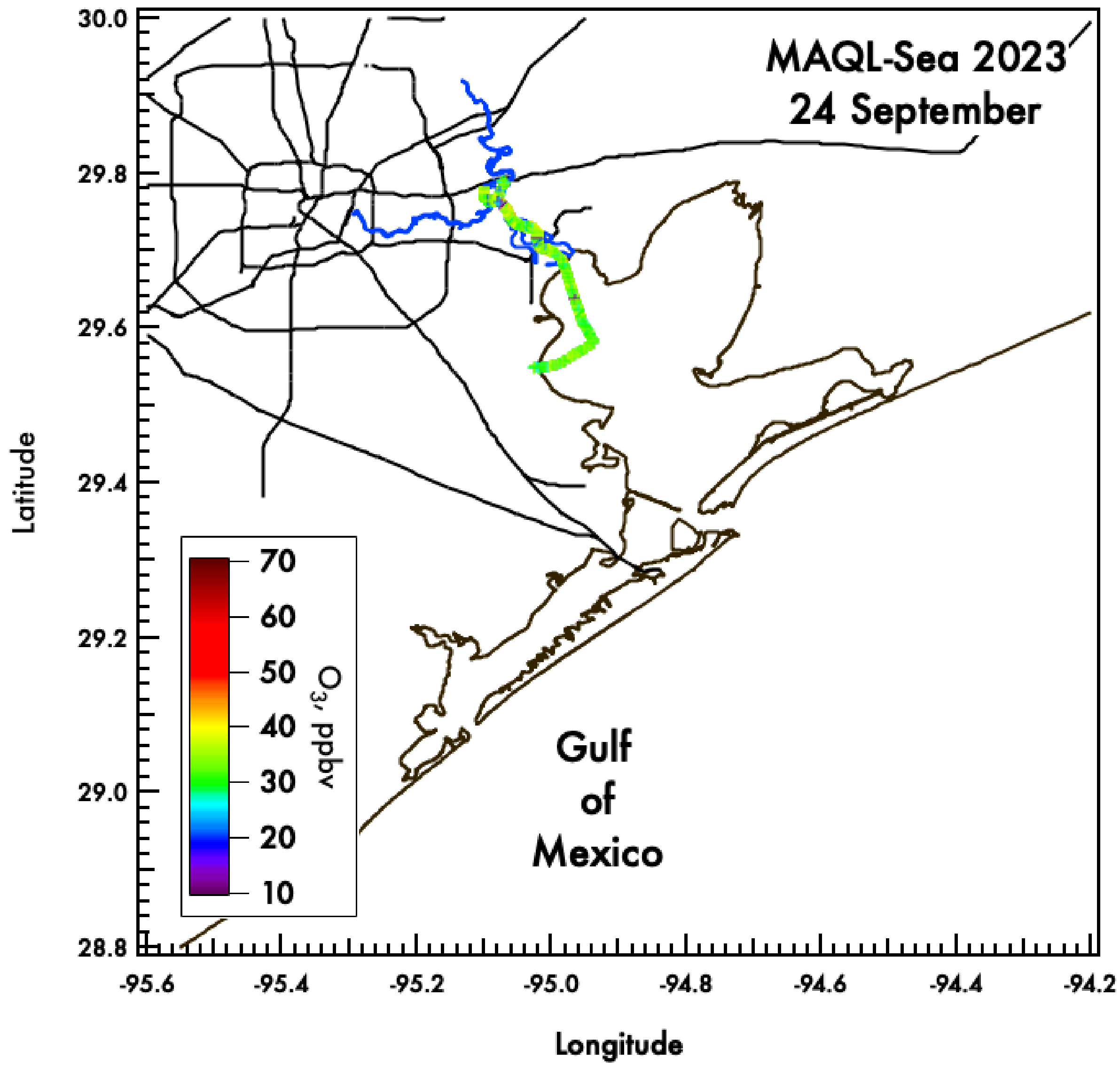

Figure 139. *Spatial plot of mobile measurement of ozone aboard MAQL-Sea boat platform on September 24, 2024.*

September 27, 2023

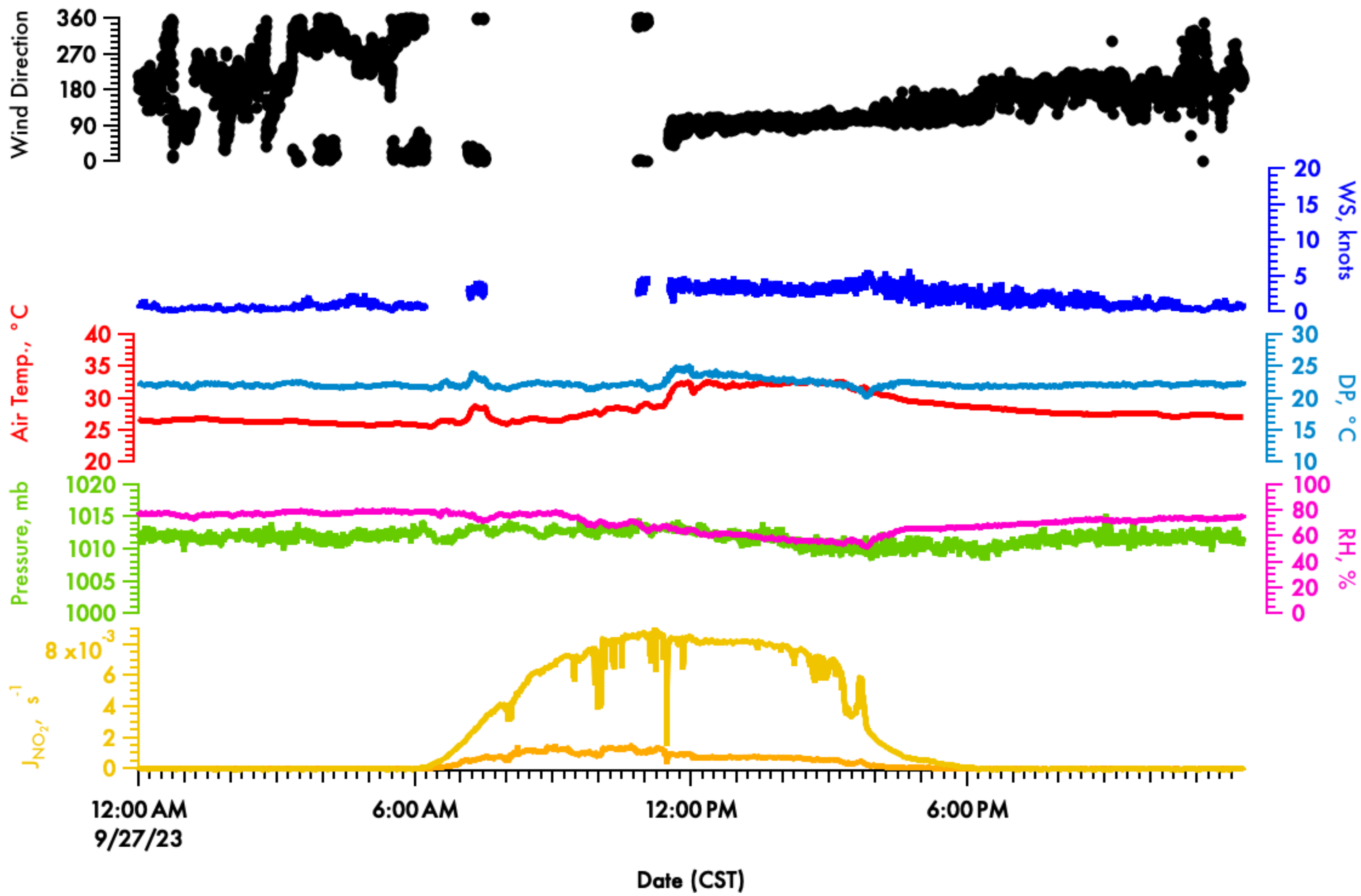

Figure 140. *Meteorological measurements were collected from the MAQL-Sea boat platform on 27 September 2023.*

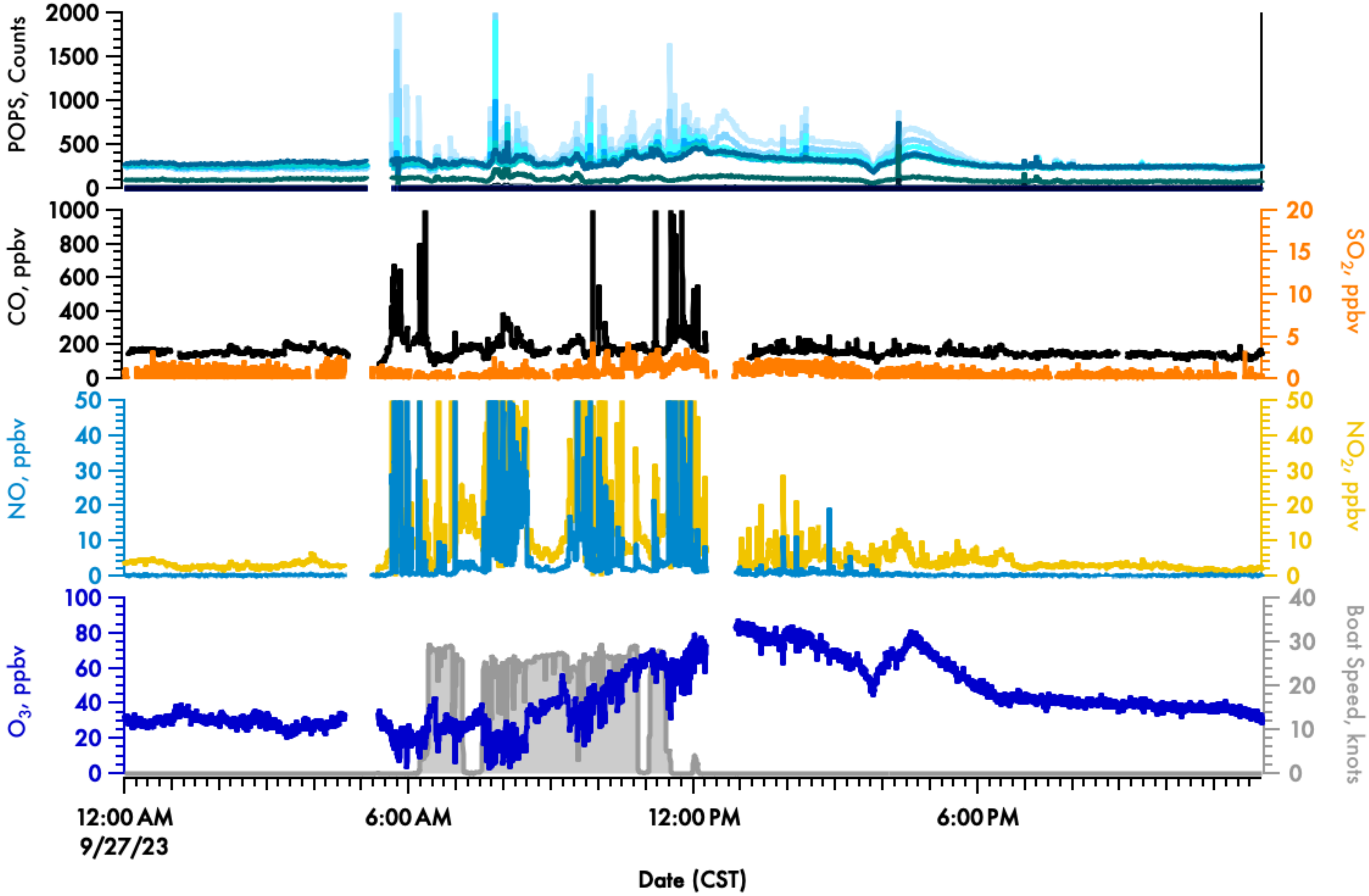

Figure 141. *Trace gases and POPS measurements collected from the MAQL-Sea boat platform on September 27, 2023.*

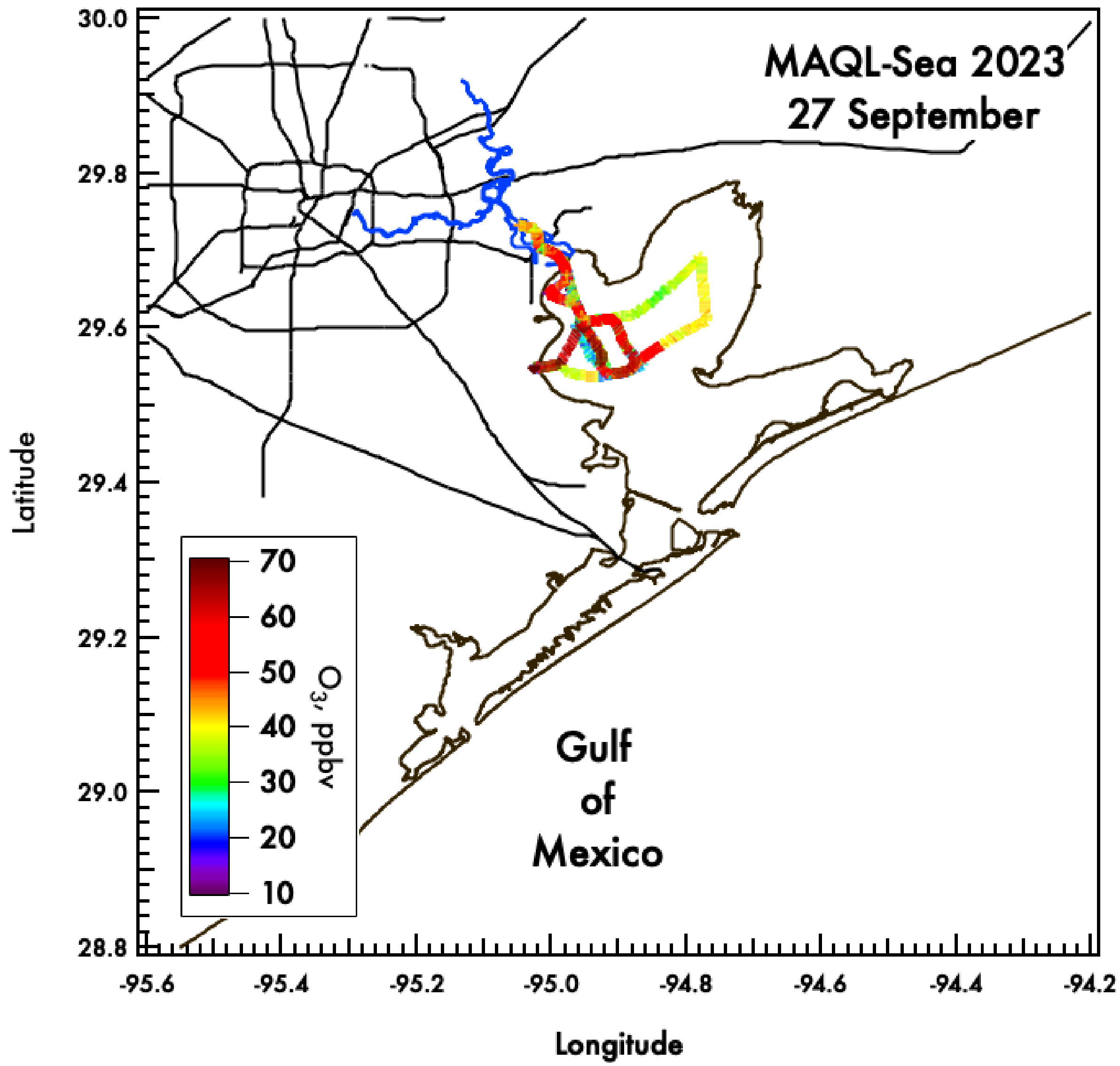

Figure 142. *Spatial plot of mobile measurement of ozone aboard MAQL-Sea boat platform on September 27, 2024.*

September 28, 2023

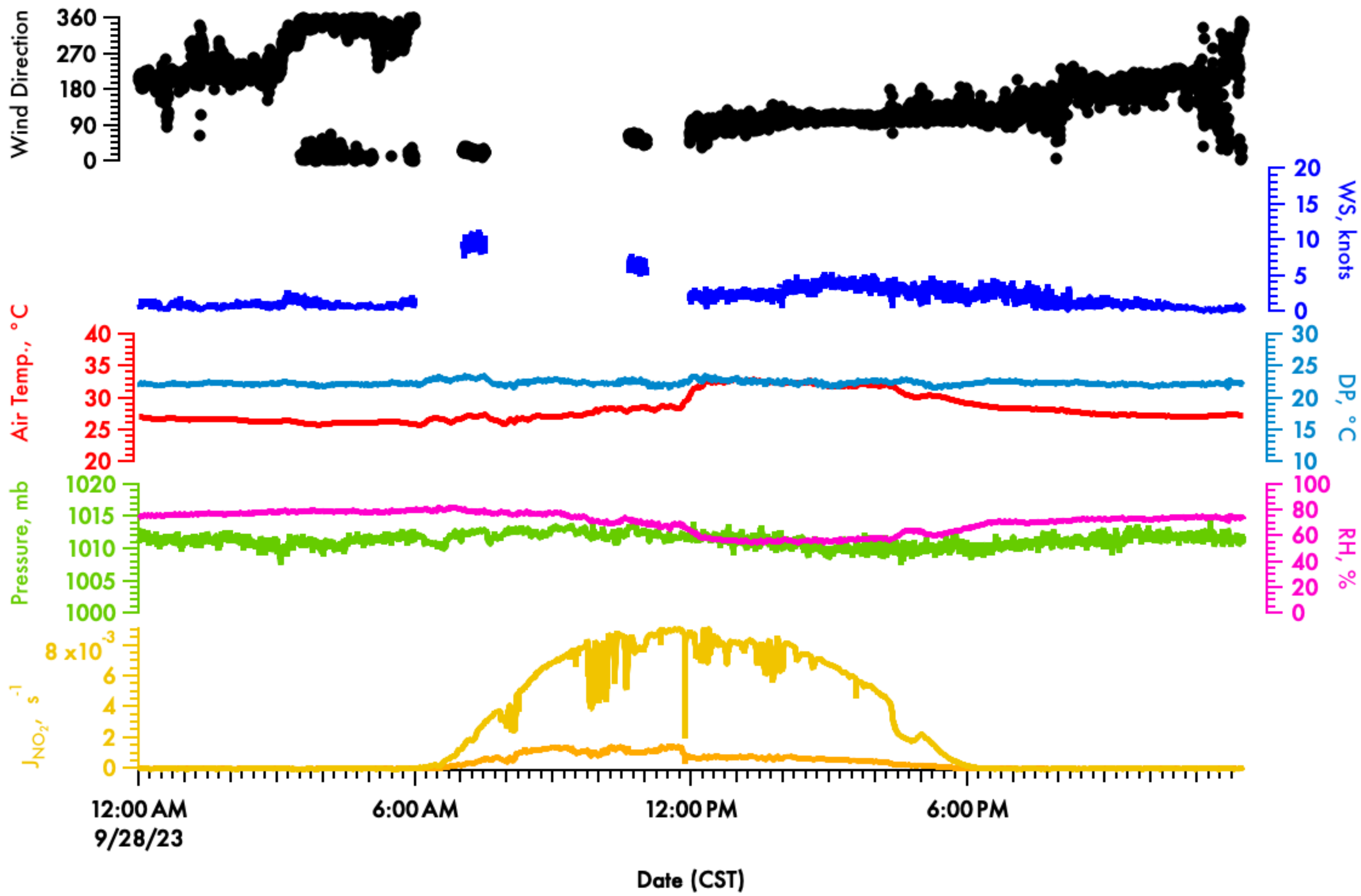

Figure 143. *Meteorological measurements collected from the MAQL-Sea boat platform on 28 September 2023.*

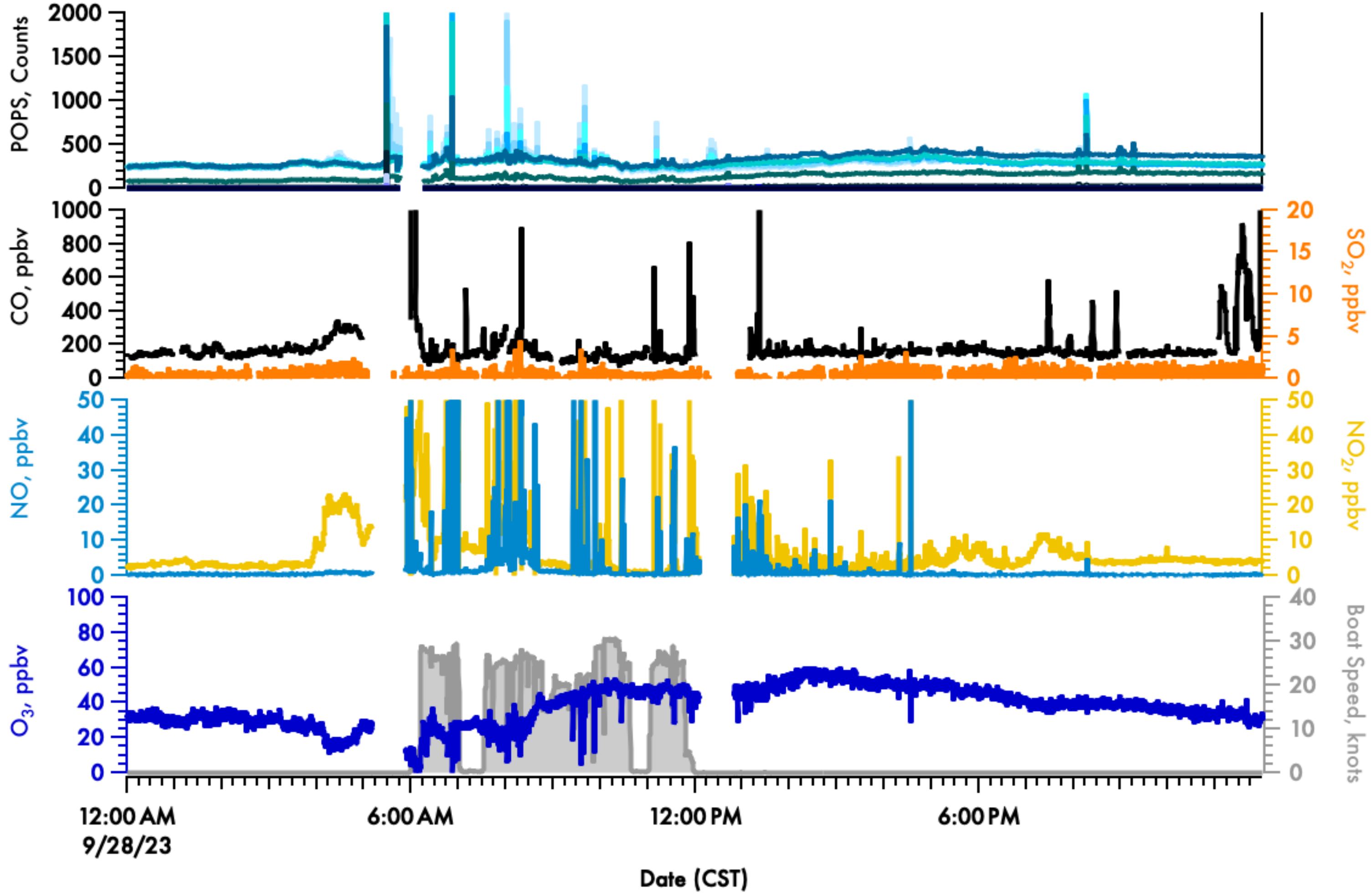

Figure 144. *Trace gases and POPS measurements collected from the MAQL-Sea boat platform on September 28, 2023.*

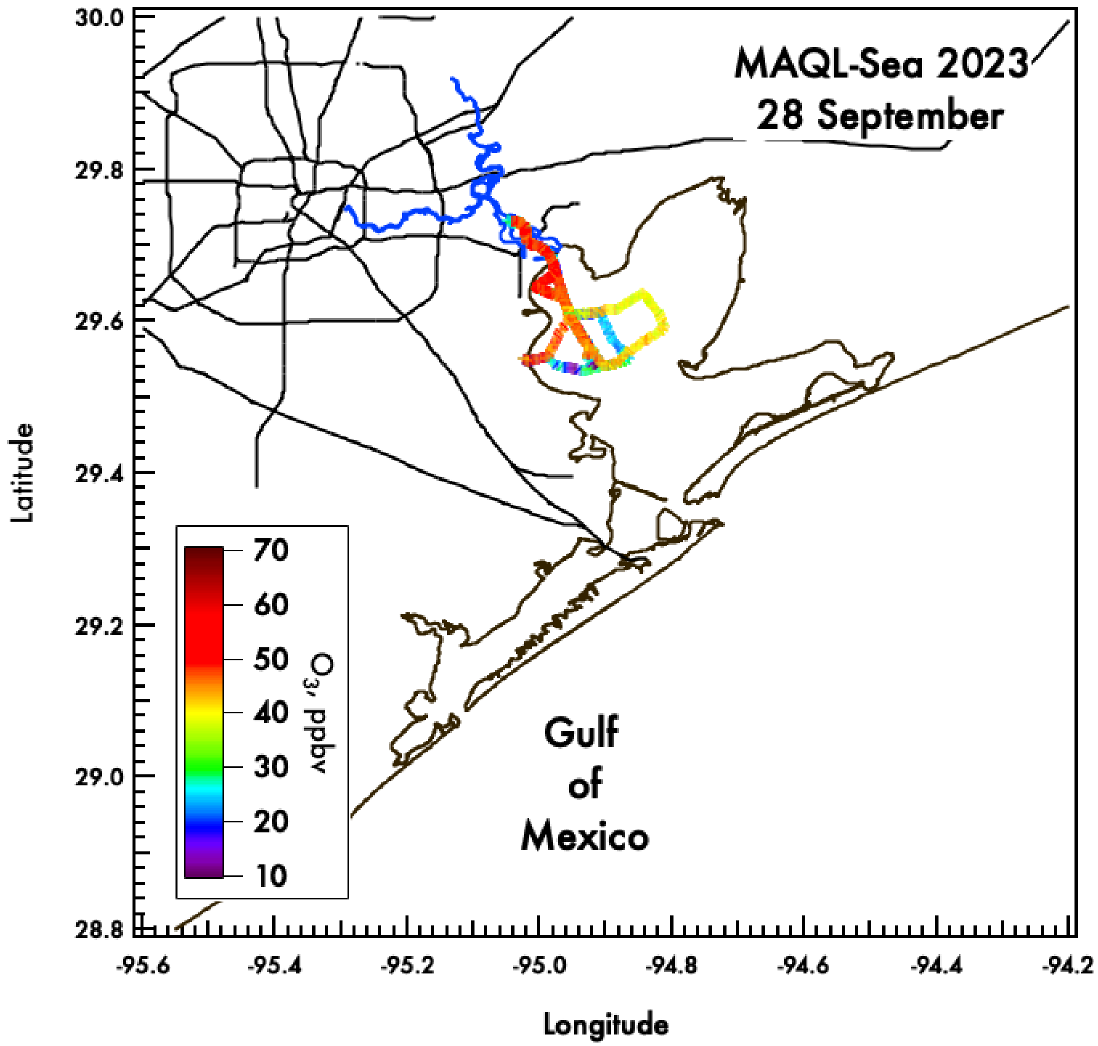

Figure 145. *Spatial plot of mobile measurement of ozone aboard MAQL-Sea boat platform on September 28, 2024*

8. Appendix C: Task 5 – Monitoring Air Quality by use of small Unmanned Aerial Vehicle (sUAS) daily figures and field notes

September 8, 2023

On September 8, the sUAS flew the standard O_3, T, P, and RH payload at UH technology bridge after the flight was delayed due to an ROTC training exercise in the flight area. The power tether was used with a generator to power the sUAS. The sUAS measured O_3 in the upper sixties at the end of the morning (see **Figure 146**). September 8 was also used to train a new Ground Control Operator (GCO).

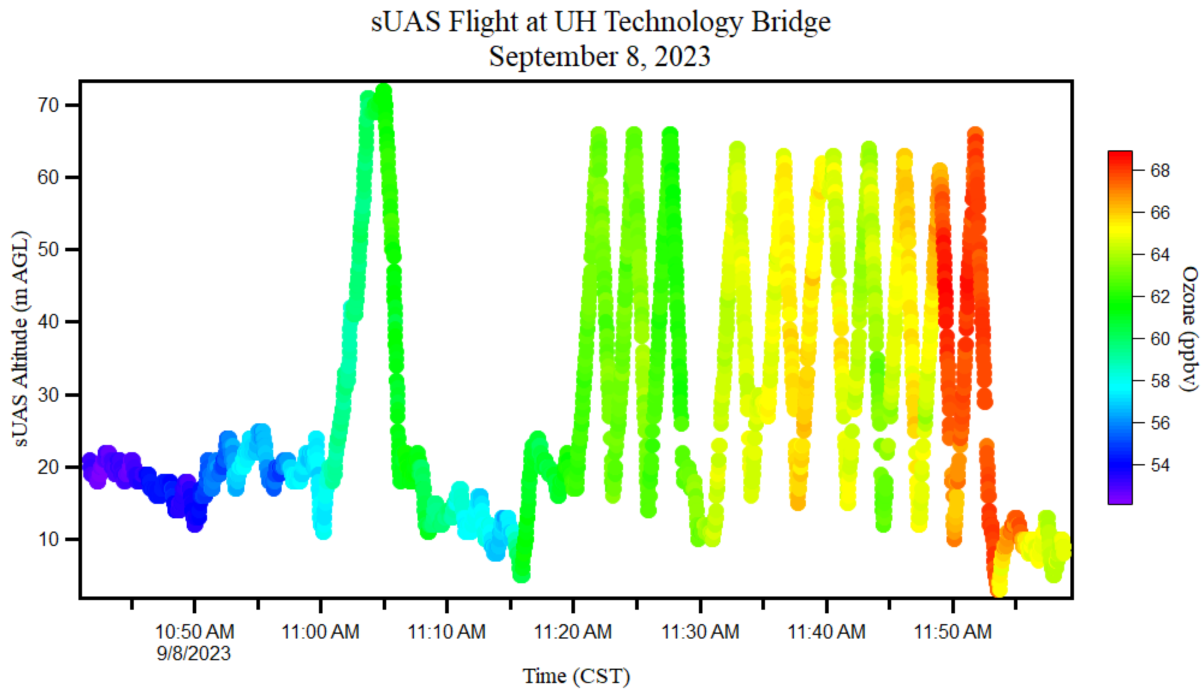

Figure 146. *sUAS altitude timeseries, colored by ozone concentration on September 8, 2023, at UH Technology Bridge. Altitude values displayed are from the GPS altitude recorded by the iMet radiosonde.*

September 10, 2023

The September 10 flight at UH Coastal Center was conducted using the power tether and began approximately ten minutes after sunrise. No strong vertical gradients were observed but a slight decrease in O_3 was measured between 6:15 and 6:30 a.m. CST (**Figure 147**).

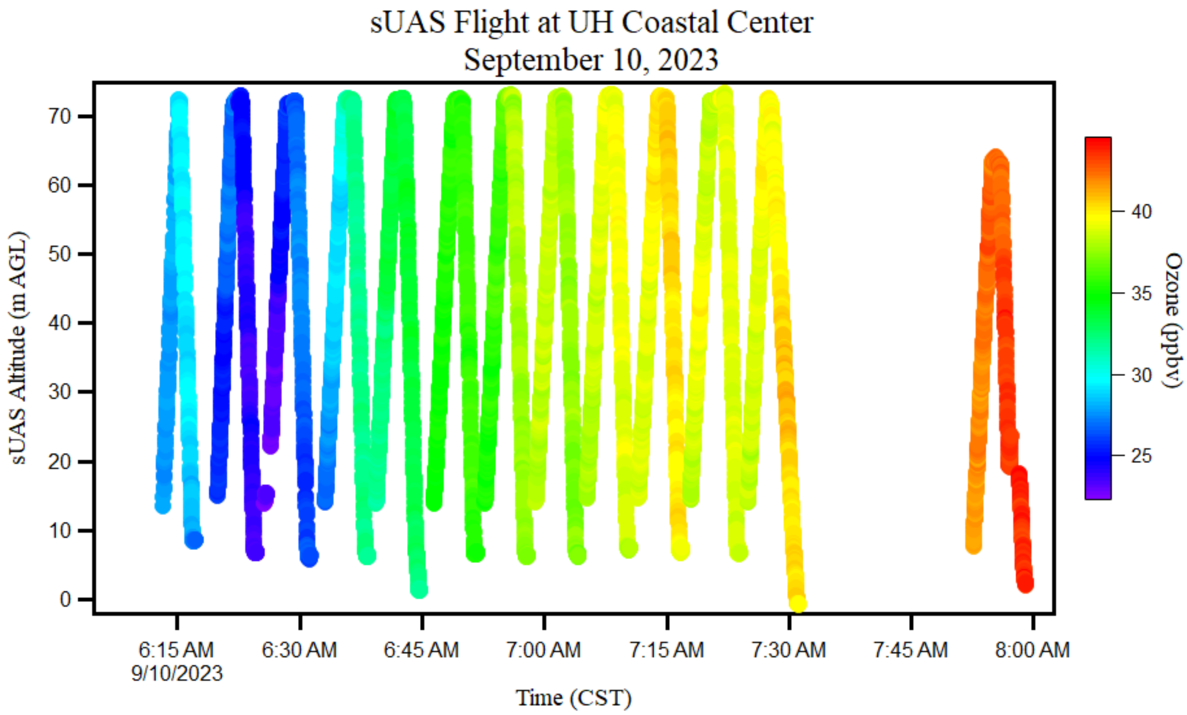

Figure 147. *sUAS altitude timeseries, colored by ozone concentration on September 10, 2023, at UH Coastal Center. Altitude values displayed are from the altitude (from the PTU sensor) recorded by the iMet radiosonde.*

September 11, 2023

Two flight periods were conducted at UH Coastal Center on September 11, which was a TEMPO special observations day (from 12:00 to 2:00 p.m. CST). The first drone launch occurred at 10:15 a.m. but the flight was short-lived due to an error from the tether. The drone was landed and the tether and onboard tether module attached to the drone were inspected, but no obvious problems were identified. A second launch was performed. No errors were present, so profiling continued until 11:12 a.m. when the sUAS was landed for a cool-down period prior to TEMPO special observations. The sUAS was active, using the power tether, through the entire special observations period and continued to sample until 2:12 p.m. measuring O_3 up to 98 ppbv (**Figure 148**). By the end of the flight, the drone altimeter was reading 19 m while the drone was on the ground indicating a problem with the altimeter.

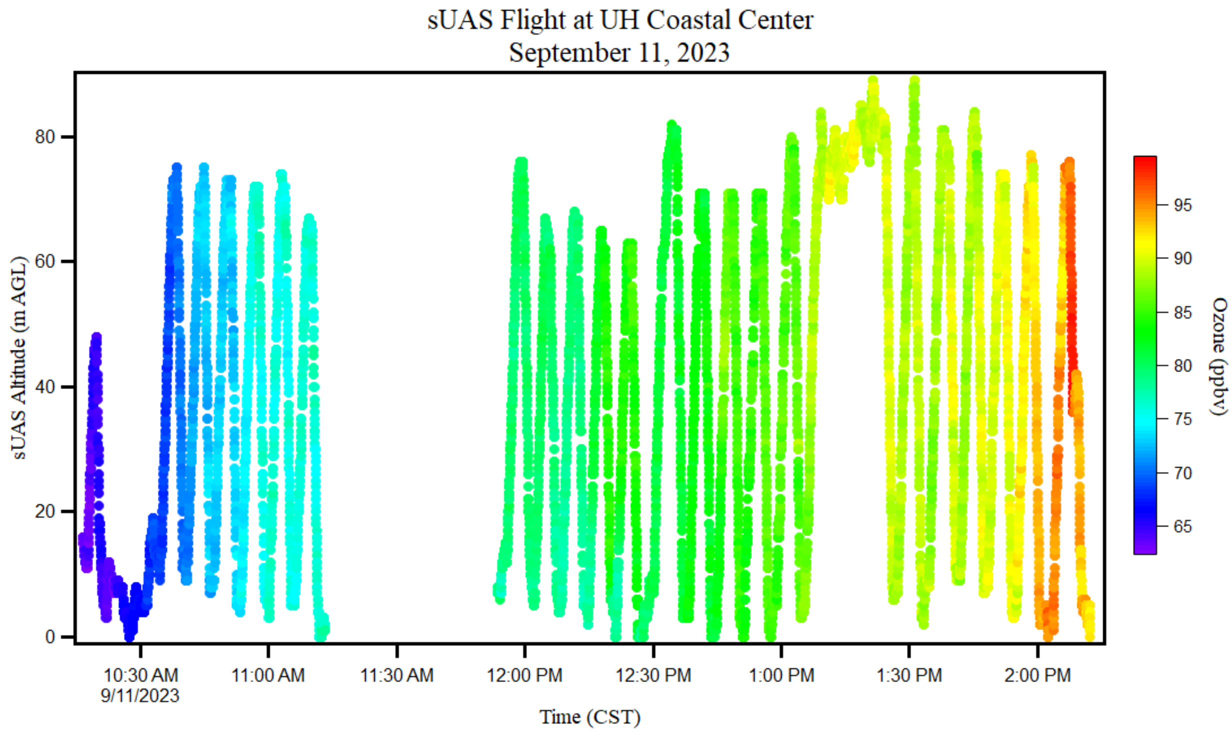

Figure 148. *sUAS altitude timeseries, colored by ozone concentration on September 11, 2023, at UH Coastal Center. Altitude values displayed are from the GPS altitude recorded by the iMet radiosonde.*

September 13, 2023

Strong ozone, temperature, and humidity gradients were observed on September 13. Winds at the surface were very calm and a mild fog was present at sunrise. **Figure 149** shows the ozone was approximately 45 ppbv greater at 70 m than at 10 m. At approximately 7:00 a.m. it was observed that temperature and humidity relationships to altitude reversed. By the time of final landing at 8:38 a.m. the gradient had mostly dissipated, and a mild breeze was felt by the RPIC at ground level.

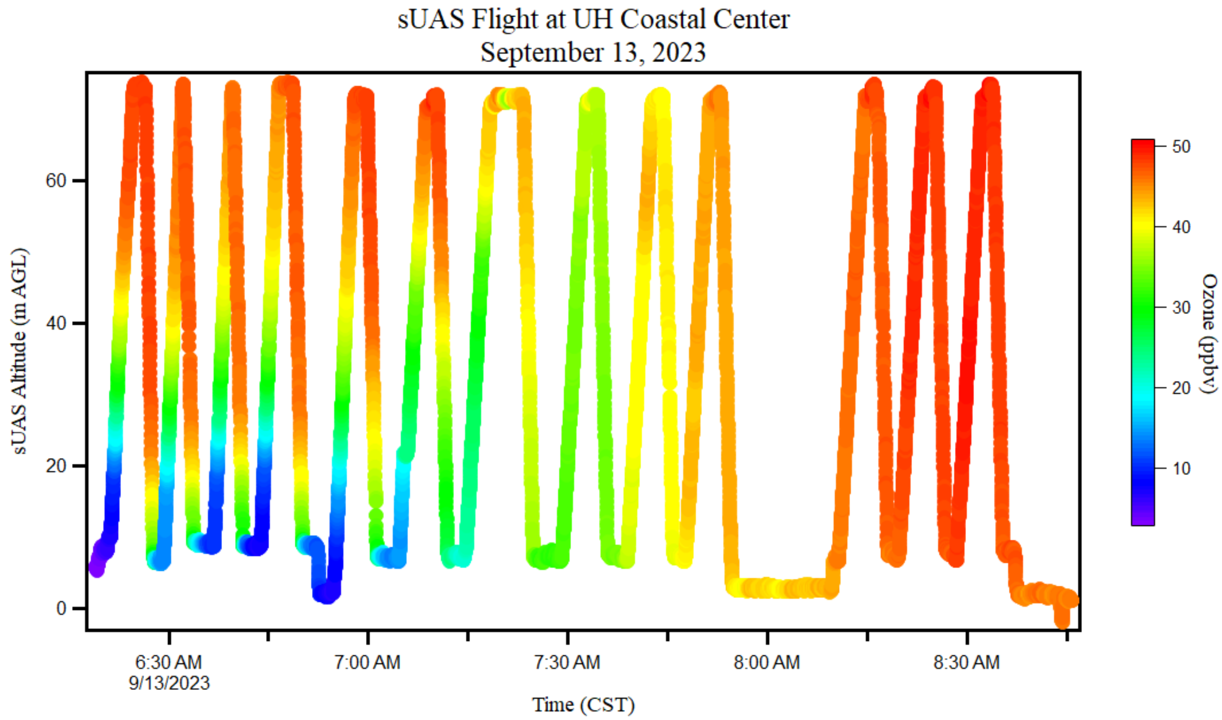

Figure 149. *sUAS altitude timeseries, colored by ozone concentration on September 13, 2023, at UH Coastal Center. Altitude values displayed are from the altitude (from the PTU sensor) recorded by the iMet radiosonde.*

September 17, 2023

TEMPO special observations occurred from 12 p.m. to 2 p.m. CST on September 17. The sUAS was deployed to UH Coastal Center for an early morning flight to make observations of early morning O_3 development and a second flight coinciding with the special observations. Winds were calm and conditions were very humid at sunrise. A new set of batteries was used for the flight to achieve higher altitudes than is possible on the power tether. A strong vertical O_3 gradient was measured (**Figure 150**) but when the drone batteries ran low, the voltage dropped quickly and the RPIC was not able to land before the propellers lost thrust. The drone fell uncontrolled into the prairie, damaging propellers, motors, the batteries, and some of the main structural components. No further flights were possible for the season.

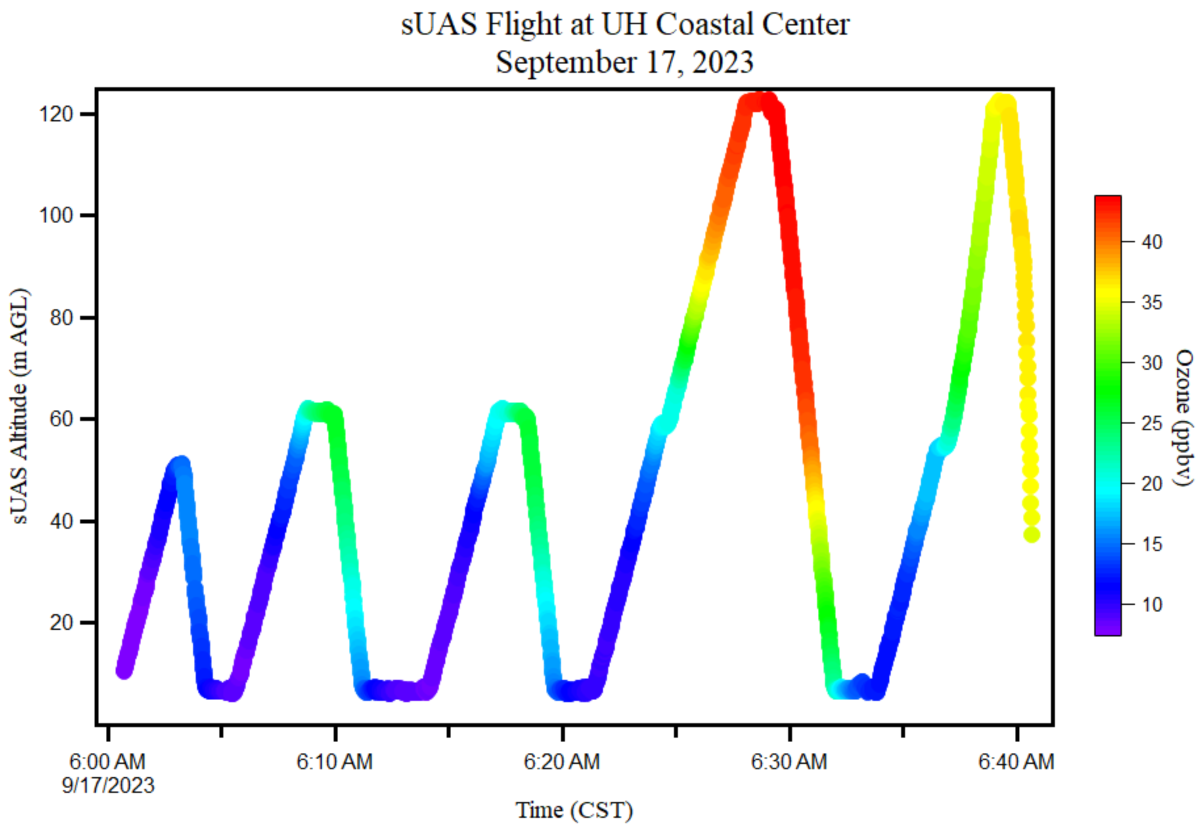

Figure 150. *sUAS altitude timeseries, colored by ozone concentration on September 17, 2023, at UH Coastal Center. Altitude values displayed are from the altitude (from the PTU sensor) recorded by the iMet radiosonde.*

9. Appendix D – Task 6 Ozonesonde Launches Profiles

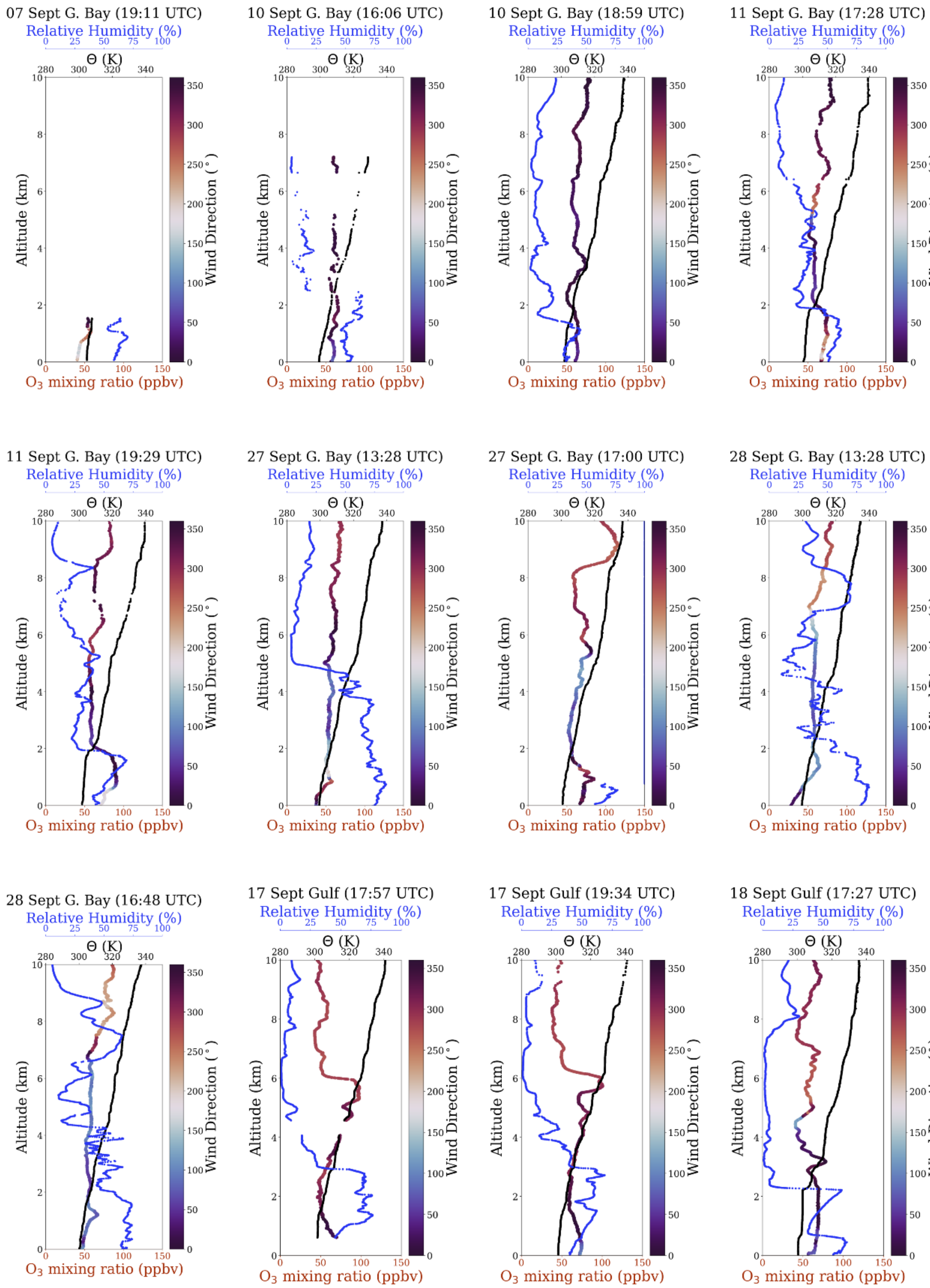

Figure 151. *Twelve of the 24 ozonesonde profiles where the first 10 km of the ascent is shown with profiles of ozone (colored by wind direction), relative humidity (blue) and potential temperature (black).*

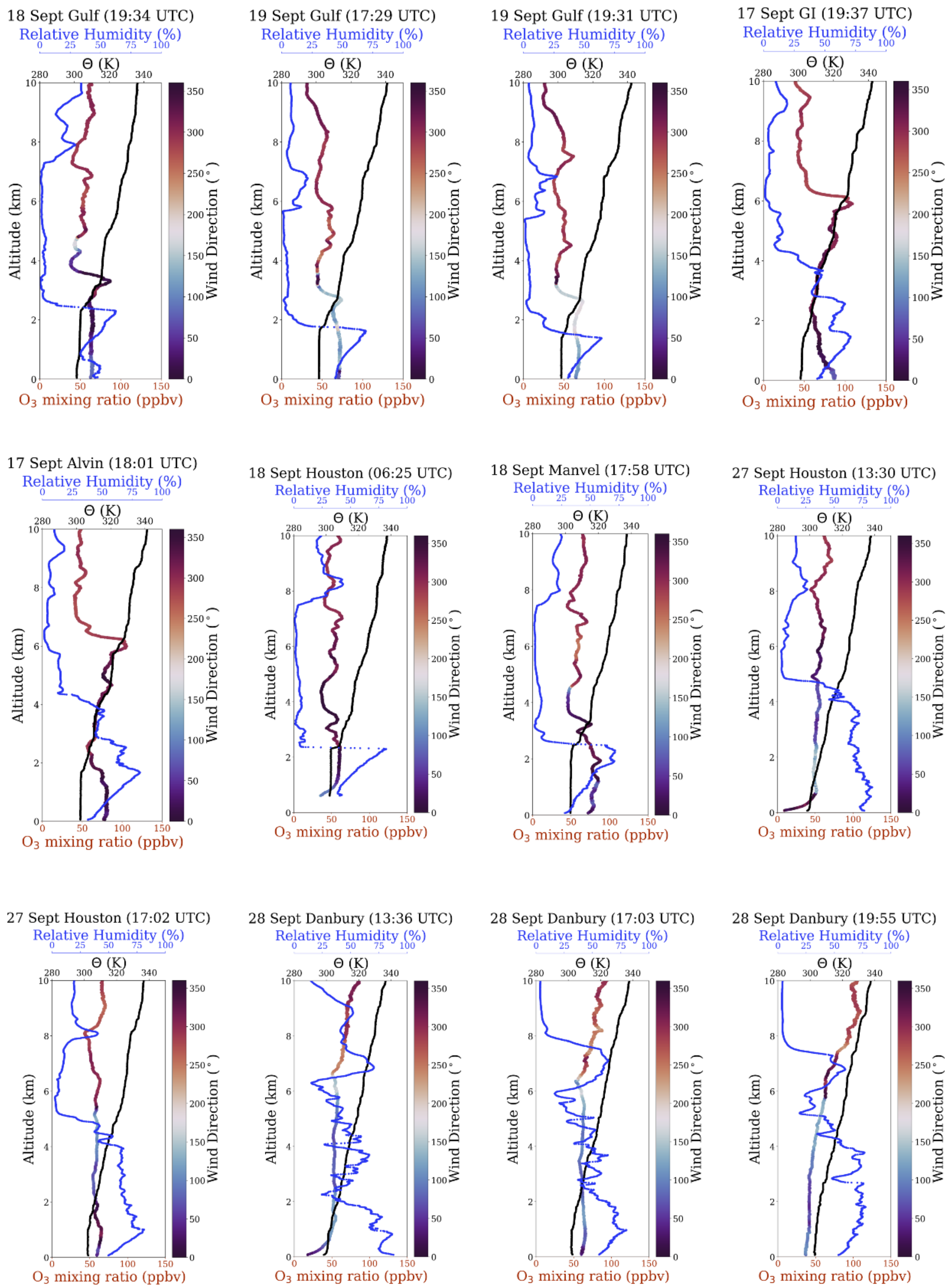

Figure 152. *The other 12 of the 24 ozonesonde profiles where the first 10 km of the ascent is shown with profiles of ozone (colored by wind direction), relative humidity (blue) and potential temperature (black).*

10. Appendix E – CTAQO green-paper

TEMPO Green-Paper Experiment Request

The TEMPO mission will conduct standard operations consisting of East-West scans every daylight hour to measure air pollutants across a Field of Regard (FoR) covering North America. Up to 25% of TEMPO's observing time will be dedicated for non-standard (hereafter referred to as high time) operations with temporal frequency as high as 10 minutes or less over selected slices of the FoR. The high time operations can be performed for a diversity of science experiments, including both fundamental and applied science research. A couple of focus areas of the high-time operations include disaster events, such as wildfires, dust storms, volcanic eruptions, and industrial accidents, in addition to various chemistry experiments aimed at further enhancing our understanding of rapidly varying emissions and air pollutants in complex environments. Coordination of science experiments for high time operations has commenced during the pre-launch phase of the mission to achieve the maximum science benefit from TEMPO data.

The purpose of this document is to build a diversity of unique and innovative science experiments for using both standard hourly and high time TEMPO data based on ideas and needs from the broader science community. Interested community members are encouraged to complete this experiment request and send to the scientific coordinators and TEMPO Principal Investigator (see footer) to be considered as a designated TEMPO high time experiment. After approval of your experiment idea, investigator names along with the experiment description will be added to the TEMPO Green Paper, unless otherwise requested by the investigators.

1) Title:

2023 Coastal Texas Air Quality Observations

2) Name of Investigator(s) including title/position, affiliation, and email:

- James Flynn, PhD: Research Associate Professor, University of Houston, jhflynn@central.uh.edu
- Paul Walter, PhD: Associate Professor, St. Edward's University, pauljw@stedwards.edu
- Rebecca Sheesley, PhD: Professor, Baylor University, rebecca_sheesley@baylor.edu
- Sascha Usenko, PhD: Associate Professor, Baylor University, sascha_usenko@baylor.edu
- Yuxuan Wang, PhD: Associate Professor, University of Houston, ywang246@central.uh.edu

- Subin Yoon, PhD: Research Scientist, University of Houston, syoon9@central.uh.edu
- Thomas F. Hanisco, PhD: Research Physical Scientist, NASA Goddard Space Flight Center, thomas.hanisco@nasa.gov
- Doug Boyer, Senior Technical Specialist, Texas Commission on Environmental Quality, doug.boyer@tceq.texas.gov
- Sushil Gautam, PhD: Technical Specialist, Texas Commission on Environmental Quality, sushil.gautam@tceq.texas.gov

3) Brief description of fundamental or applied research experiment and role of TEMPO data:

In August and/or September 2023, four weeks of intense monitoring will occur onshore and offshore of Houston, Texas to study the transport and formation of ozone and particulate matter. Three ship-based platforms will include in-situ trace gas (ship-dependent O_3, O_X, NO, NO_2, SO_2, CO, $PM_{2.5}$ size distribution and optical properties, and/or VOCs), meteorology, one Pandora, two ceilometers, and ozonesonde measurements in Galveston Bay and the Gulf of Mexico to study the over-water interaction of atmospheric chemistry and meteorology where surface monitoring sites do not exist. Onshore measurements from a mobile air quality laboratory (O_3, NO, NO_2, SO_2, CO, VOCs, HCHO, isoprene, $PM_{2.5}$ size distribution and optical properties, meteorology), instrumented drone (O_3 and/or VOCs), Pandoras, stationary sites, and ozonesondes will complement the offshore measurements to evaluate the interaction of the sea/bay breezes and other transport conditions on surface and aloft air quality. The 2023 measurements will follow on the 2021 and 2022 TRacking Aerosol Convection ExpeRiment – Air Quality (TRACER-AQ) field campaigns (Jensen et al., 2022; Judd et al., 2021), providing a unique three-year span of August/September measurements in the Houston area and surrounding waters. The addition of high-frequency TEMPO data in 2023 will enhance the spatiotemporal observations of air quality (including the HCHO/NO_2 ozone formation sensitivity ratios) throughout the Houston area, especially for dynamic atmospheric processes like sea/bay breezes, boundary layer development, and mixing of aloft residual layers. The TEMPO observations will provide important validation data for future photochemical modeling used in the State Implementation Plan process. The surface trace gas and Pandora and ozonesonde measurements from the campaign will provide a unique onshore and offshore dataset to evaluate the TEMPO retrievals. TEMPO special operations of the campaign would provide a test during the satellite's commissioning phase, which would develop confidence in future special ops like the May-June 2024 Satellite Coastal and Oceanic Atmospheric Pollution Experiment (SCOAPE-II) measuring air quality in the Gulf of Mexico.

Jensen, M. P., Flynn, J. H., Judd, L. M., Kollias, P., Kuang, C., Mcfarquhar, G., Nadkarni, R., Powers, H., & Sullivan, J. (2022). A Succession of Cloud, Precipitation, Aerosol, and Air

Quality Field Experiments in the Coastal Urban Environment. *Bulletin of the American Meteorological Society*, *103*(2), 103–105. https://doi.org/10.1175/BAMS-D-21-0104.1

Judd, L. M., Investigator, T.-A. C.-P., Sullivan, J. T., Investigator, T.-A. C.-P., Lefer, B., Haynes, J., Jensen, M. P., & Nadkarni, R. (2021). *TRACER-AQ Science Plan: An Interagency Cooperative Air Quality Field Study in the Houston, TX Metropolitan Region*. https://www-air.larc.nasa.gov/missions/tracer-aq/docs/TRACERAQ_SciencePlan_v1.pdf

4) Explain potential societal benefits from the application experiment, including any specific stakeholder views:

Results from this study are expected to improve the understanding of ozone and particulate matter formation and transport, which will directly impact the air quality planning process of attaining and/or maintaining the ozone and $PM_{2.5}$ National Ambient Air Quality Standards in Texas. The field campaign and TEMPO observations should yield ozone production sensitivity spatially and temporally, which can inform policy decisions on the effectiveness of potential emission reductions. These observations will validate and improve photochemical models used by the research and air quality management communities.

5) List the TEMPO data products (Data Table) needed for the experiment:

- Ozone profile, total column, tropospheric column, and near-surface column
- NO_2 tropospheric column and slant column densities
- HCHO tropospheric column and slant column densities
- SO_2
- Aerosol, all measures
- BrO
- Cloud properties
- UV irradiance
- TEMPO/GEOS-R Synergistic: aerosol, cloud & mask, fire/hotspot

6) Is low data latency important? If yes, what is the requirement in hours or days?

Latency - time between satellite observation and time data are made available to users

No.

7) Does the experiment require use of other satellite (non-TEMPO) data? If yes, what instruments and data products?

MODIS AOD and VIIRS fire detects

GOES-R cloud mask, fire detects

8) Area(s) of interest – specify latitude and longitude bounds:

Minimum bounds: 27.00° to 31.00°, -97.0°0 to -93.25°

Optimal bounds: 25.75° to 34.00°, -99.00° to -89.50°

9) Period(s) of interest (e.g., days of week, month, season, full year):

Mid-August through September 2023.

High time experiments require responses to the following:

10) Explain need for high time (e.g., <= 10 minute) observations. How will high time data improve the experiment over standard hourly data?

High temporal resolution satellite observations should be able to track the evolution of the sea/bay breezes, which can begin within minutes and affect parts of the coastal areas at different times. The complex mixing of the marine and land atmospheric boundary layers also necessitates high temporal observations to understand the impact on air quality. High temporal observations may provide emission signatures of individual ships in the Gulf of Mexico and the Ship Channel through Galveston Bay as well as onshore point source emission temporal variability. Ozone formation sensitivity may also exhibit large spatiotemporal variability due to localized plumes and emissions that requires high temporal observations of the $HCHO/NO_2$ ratio to pinpoint changes in NOx and VOC sensitivity regimes.

11) Desired repeat time (e.g., daily, weekly) during period of interest:

Daily