PROJECT TITLE	Integrated Airborne-Mobile Ground Observations and Inventory for Enhanced VOC Source Attribution and Ozone Precursor Mapping in Texas	**PROJECT #**	26-029
PROJECT PARTICIPANTS	**PIs:** Pawel Misztal, Lea Hildebrandt Ruiz, Yue Zhang, Nathan Malarich, Munkhbayar Baasandorj **Students and Postdocs:** *TAMU:* Alana Dodero, Jiayun Zhao, Alexander Treadway, John Gonzales, Rajab Mammadov *UT Austin:* Keuntaek Kim, Hyeonjun Lee, Chun-Ying Chao, Shihao Zhai, Daniel Sung, Sam Lin, Kat Konon *CU Boulder/NOAA:* Nathan Malarich	**DATE SUBMITTED**	07/10/2026
REPORTING PERIOD	**From: 6/01/2026 To: 7/10/2026**	**REPORT #**	3

A Financial Status Report (FSR) and Invoice will be submitted separately from each of the Project Participants reflecting charges for this Reporting Period. I understand that the FSR and Invoice are due to the AQRP by the 15th of the month following the reporting period shown above.

Detailed Accomplishments by Task for reporting period

Task 1: The TexAQS 2026 mobile field campaign concluded during this reporting period. Following the Dallas–Fort Worth and Houston deployments reported previously, the team completed mobile measurements in San Antonio (beginning June 13, 2026) and Austin (June 18–19, 2026). The full mobile field phase is now complete across all four target metropolitan areas. The project has since transitioned to post-campaign data processing, quality assurance, and intercomparison with the TAMU, University of Houston, NOAA, and Houston supersite datasets. During the progress meeting in early July the teams presented preliminary data and specified a period for select VOC comparison: spiral location in the Dallas-Fort Worth (DFW) area, during the high ozone day.

Dallas–Fort Worth (May 29 – June 4, 2026)

The Dallas–Fort Worth deployment was reported in the previous MTR and is summarized here for completeness. The team completed a seven-day mobile deployment across ten planned routes per platform, with the UT and TAMU platforms sampling shared corridors in opposite directions to support cross-platform comparison and to capture upwind and downwind gradients. Routes targeted data center and airport areas. The team co-sampled with TAMU near the NOAA P-3 spiral site at Azle and conducted co-location at a TCEQ monitoring station near the University of Texas at Arlington. En route from Austin on May 29, the team also fingerprinted industrial facilities near Waxahachie.

Houston (June 6 – June 12, 2026)

The team completed the Houston deployment across repeated routes on both mobile platforms, concentrating on the ship channel corridor and on industrial and waste-management sources, with paired opposite-direction drives with TAMU. Stationary measurements continued at the Houston supersite throughout the week, and the UT van sampled at the Pleasantville community site to provide an upwind and downwind contrast with the supersite. Collocated drives were conducted with the TCEQ mobile laboratory, and ground-air co-location was performed near the NOAA P-3 spiral site east of Houston.

San Antonio (June 13-18, 2026)

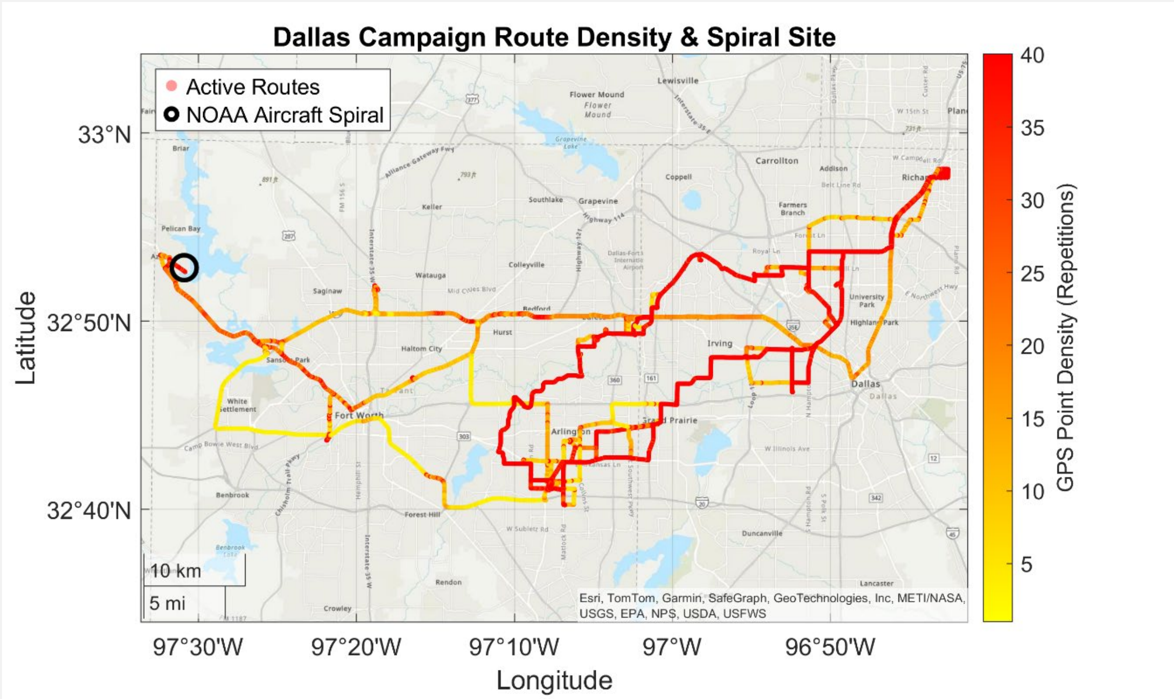
The team completed the San Antonio deployment following the planned route design, with the UT mobile platform covering repeated tracks across the metropolitan area. Source-relevant environments targeted during the San Antonio drives included industrial corridors, quarry and cement operations, wastewater facilities, and major highway and airport areas. Coordinated sampling with the UT and TAMU mobile platforms followed the paired opposite-direction route approach used in the earlier metros to improve spatial coverage and support cross-platform comparison.

Austin (June 18–19, 2026).

The Austin deployment followed San Antonio and was conducted as an initial investigation since the main focus was on DFW, Houston and San Antonio. The UT Austin team conducted this pilot on the way to Austin while the TAMU team drove to a different commitment. Further dedicated joint campaign with TAMU in Austin is envisioned later in the Fall semester to assemble comparable data with other 3 metropolitan areas. Austin pilot drives targeted data centers, EV and semiconductor manufacturing, wastewater, and other sources in southeast Austin. Ground–air collocation with the aircraft was pursued during the overlapping passes to support comparison of mobile ground-based observations with the airborne platform.

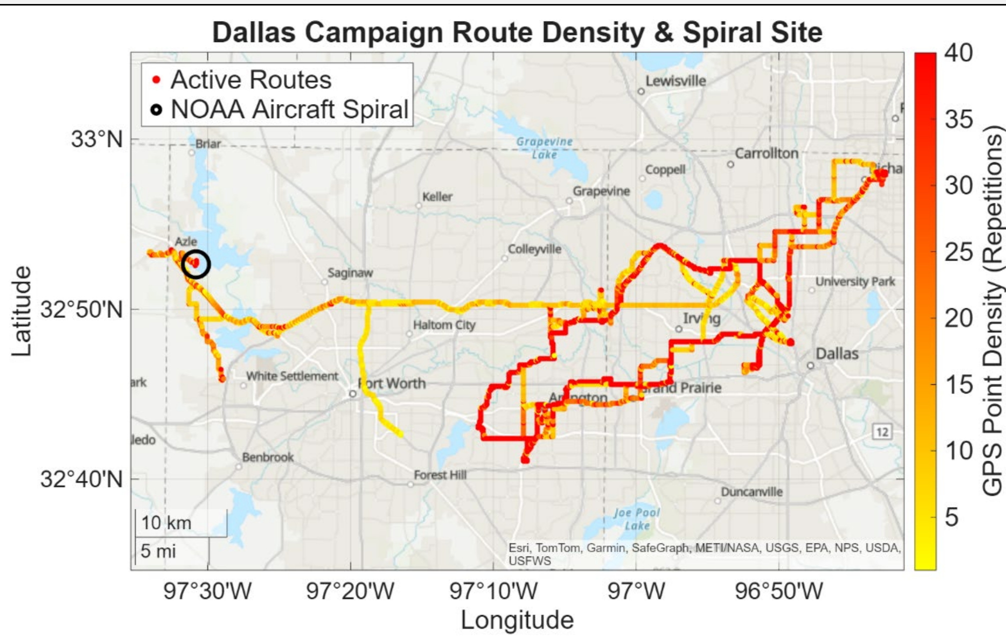
Figures 1 through 4 show the cumulative GPS density of completed driving routes for Dallas–Fort Worth, Houston, San Antonio, and Austin. Each figure presents the TAMU mobile platform panel (A) and the UT Austin mobile platform panel (B). The Dallas–Fort Worth route density was finalized in the previous reporting period and is reproduced here for completeness. The campaign followed the planning approach described in the approved Work Plan, with at least 20 repeats of the tracks in each metropolitan region (10 per mobile lab) and two approximately 3-hour drives per day. Industrial sources, waste management sources, and data centers remained the focal sources, in addition to airport areas and the Houston ship channel corridor. CAMS auto-GC and VOC canister locations were used as collocation opportunities throughout the campaign.

(A) TAMU



(Figure credit: A. Dodero TAMU)

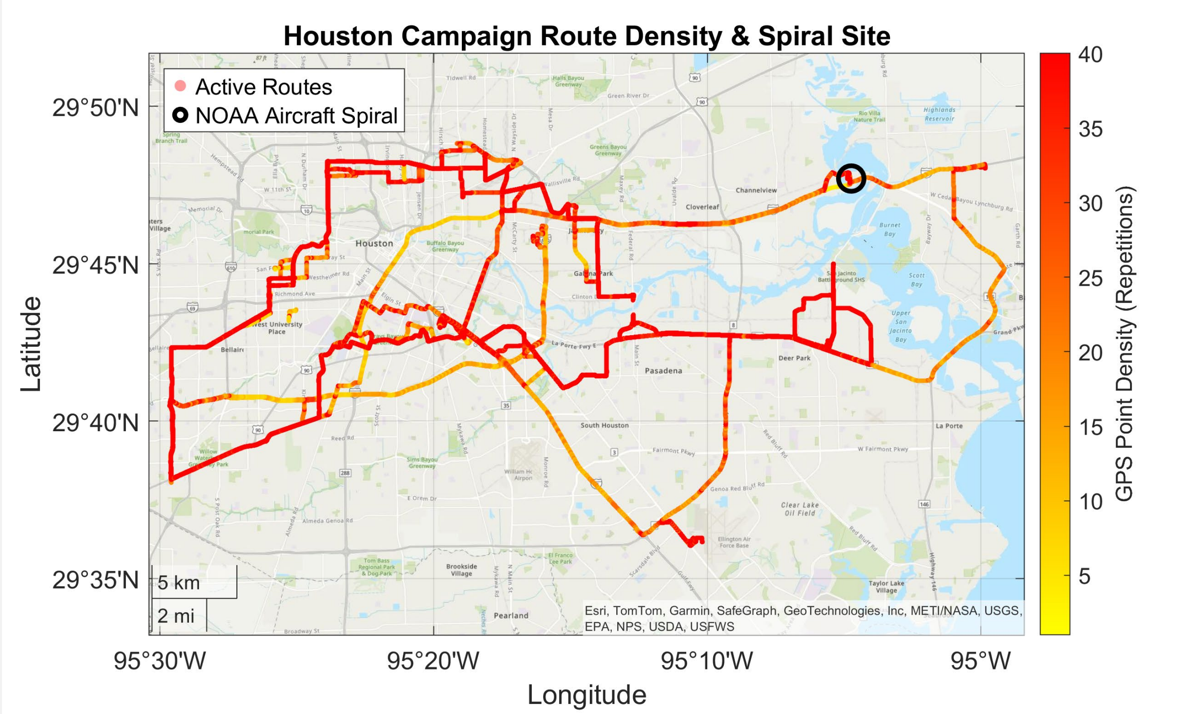
(B) UT Austin



(Figure credit: K. Kim UT Austin)

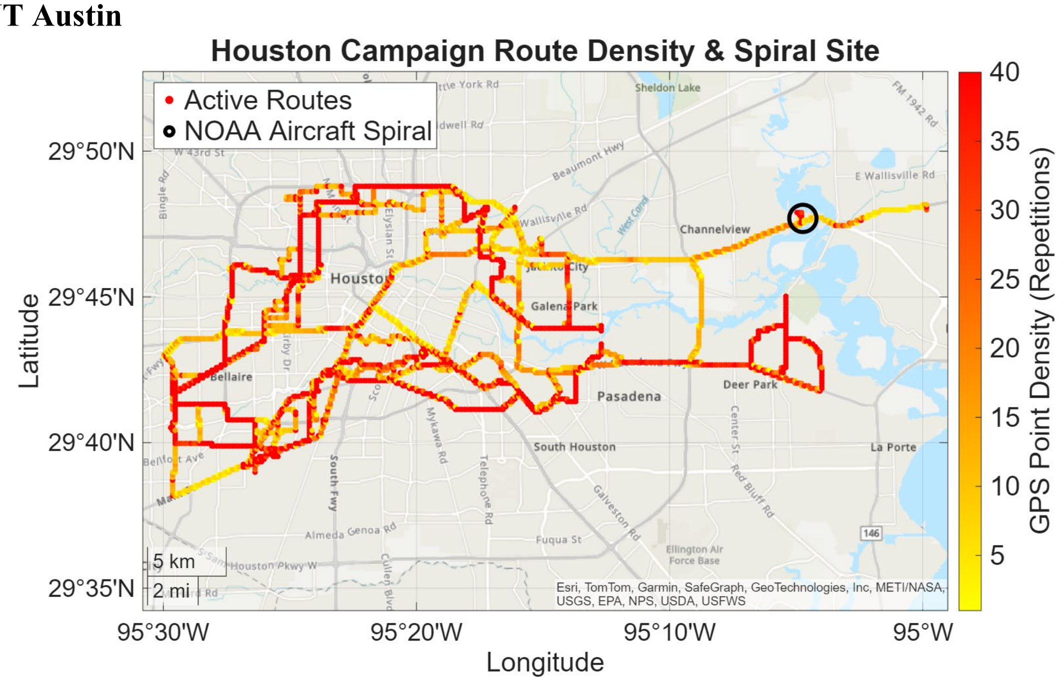
Figure 1. *Completed mobile sampling route density in the Dallas–Fort Worth metropolitan area, aggregated from the (A) TAMU and (B) UT Austin mobile platforms. Color scale indicates GPS point density (repetitions). The black circle marks the NOAA aircraft spiral site near Azle, TX. Dallas–Fort Worth route density is final and reproduced here from the previous reporting period.*

(A) TAMU



(Figure credit: A. Dodero TAMU)

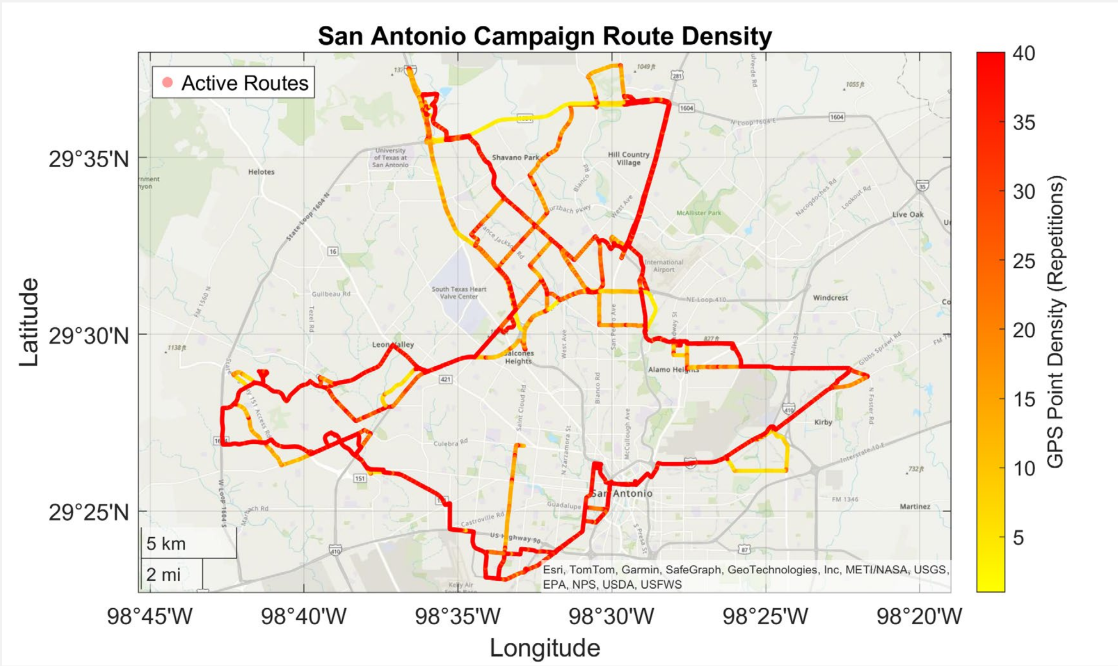
(B) UT Austin



(Figure credit: K. Kim UT Austin)

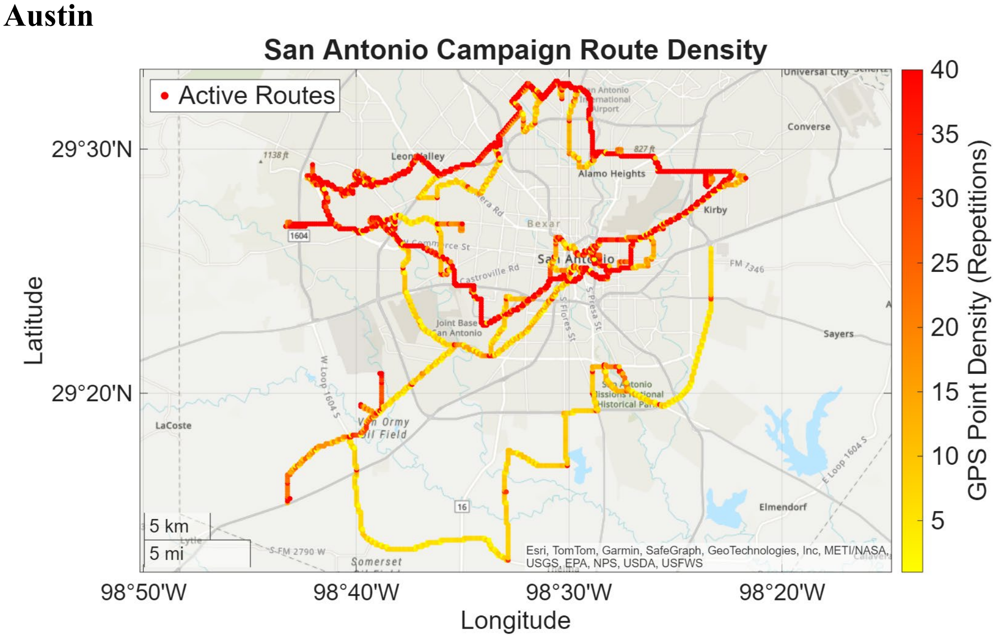
Figure 2. *Completed mobile sampling route density in the Houston metropolitan area, aggregated from the (A) TAMU and (B) UT Austin mobile platforms. Color scale indicates GPS point density (repetitions). The black circle marks the NOAA aircraft spiral site east of Houston.*

(A) TAMU



(Figure credit: A. Dodero TAMU)

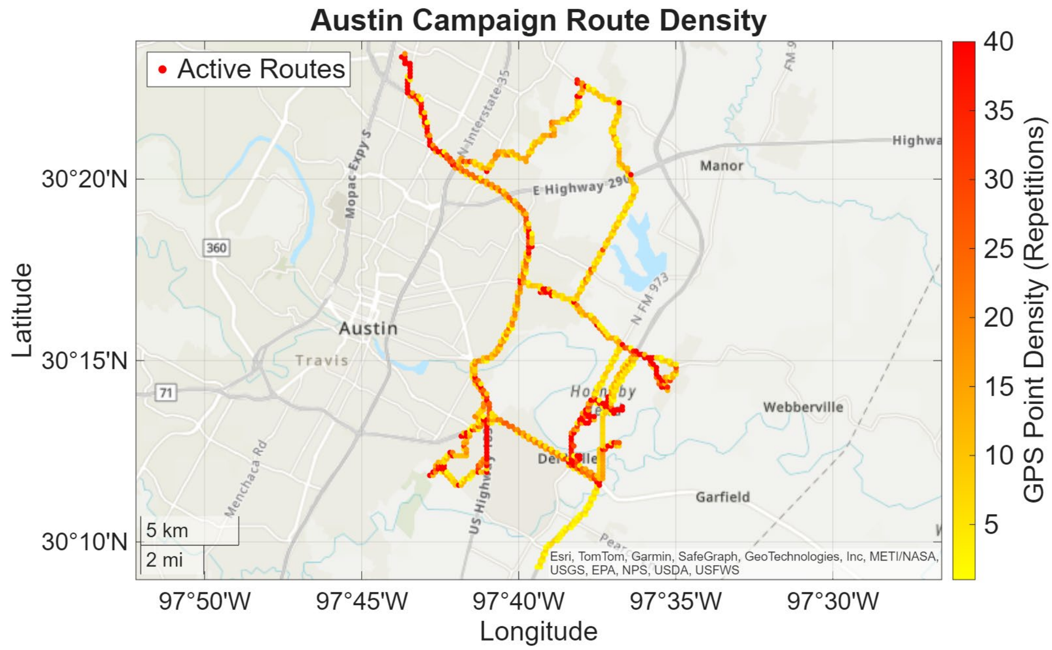
(B) UT Austin



(Figure credit: K. Kim UT Austin)

Figure 3. *Completed mobile sampling route density in the San Antonio metropolitan area, aggregated from the (A) TAMU and (B) UT Austin mobile platforms. Color scale indicates GPS point density (repetitions).*

UT Austin



(Figure credit: K. Kim UT Austin)

Figure 4. *Completed mobile sampling route density in the Austin metropolitan area, aggregated from the UT Austin mobile platform. Color scale indicates GPS point density (repetitions).*

Stationary measurements continued at the Houston supersite throughout the campaign, led by Yue Zhang, James Flynn, and NOAA, through a ground supersite with more than 20 instruments including four mass spectrometers to provide comprehensive quantification of both gas and particle phase species. The UT HR-ToF-AMS and UT Picarro HCHO/CH4 instruments were deployed at the supersite as part of this project. Collocated drives were conducted with the TCEQ mobile laboratory team as well as the University of Houston (Jimmy Flynn) lab. The UT van also sampled at the Pleasantville community location to provide upwind and downwind comparison with the supersite.

Preliminary Analysis

<u>Mobile Measurements</u>

Preliminary inspection of real-time Vocus and other data across the campaign continues. The groups meet regularly and discuss current progress. Select preliminary results are shown below and will further be complemented in the next monthly reports.

In total mobile platforms completed approximately 5,000 data km/lab over 150 h/lab. The exact totals by metropolitan area by van are summarized in Table 1 below.

Table 1. *Distances and times driven with instruments collecting data*

Metropolitan area	**Data drive distance (km)***	**Data drive time (h)***
Dallas–Fort Worth	1,836	52.25
Houston	1,314	45.33
San Antonio	1,375	43.10
Austin	402	10.03
Total	4,927	150.7

**Based on UT van (analysis by K. Kim). Similar driving distances have been accomplished by TAMU lab in DFW, Houston and San Antonio.*

Mobile Measurements (UT Austin)

UT Austin team have processed the Vocus data from the mobile platform and as well as calibrated the data to preliminary stage. While further QC/QA are ongoing, preliminary spatiotemporal maps for the benzene ion are shown below. Although the VOC compositions change across different cities and near sources, the benzene maps shown in Figures 5-8 serve as example and reflect overall picture of spatiotemporal hotspots associated with fossil fuel combustion, petrochemical production and processing and other sources like asphalts and motor vehicles. $C_6H_6^+$ ion was calibrated explicitly based on regular twice-daily multistep calibrations, avoiding interference from higher aromatics as proposed by Coggon et al. (2024).

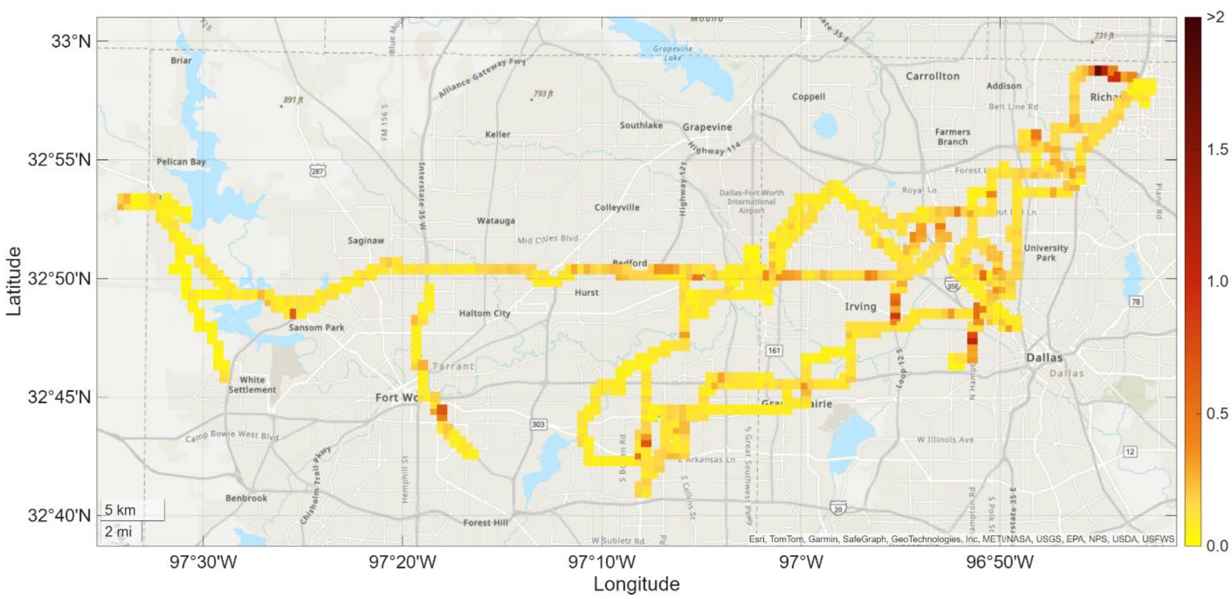


Figure 5. *Spatial distribution of $C_6H_6^+$ m/z 78.0465 in Dallas. Values are grid-cell means on a 500 m grid. Preliminary data (Figure credit: K. Kim UT Austin).*

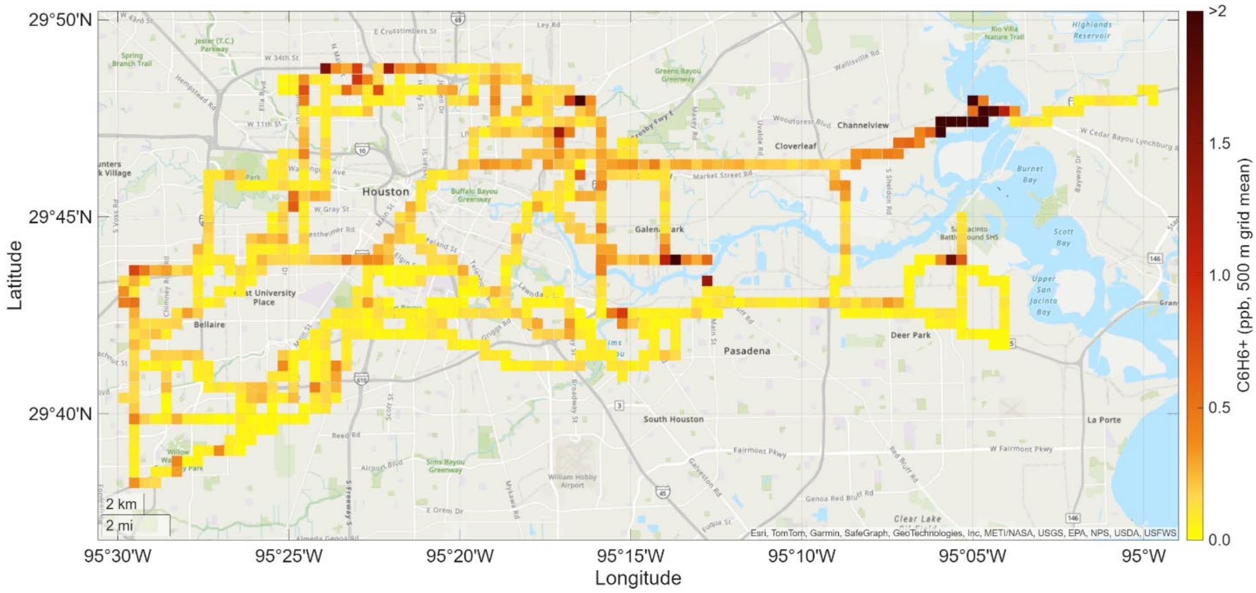


Figure 6. *Spatial distribution of $C_6H_6^+$ m/z 78.0461 in Houston. Values are grid-cell means on a 500 m grid. Preliminary data (Figure credit: K. Kim UT Austin).*

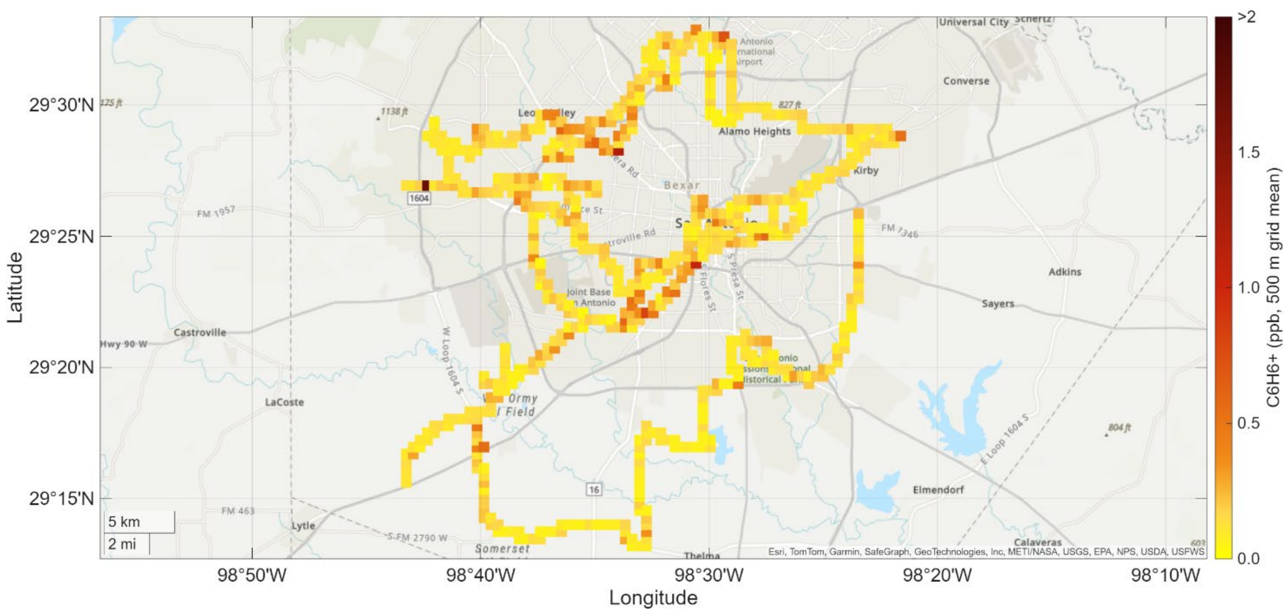


Figure 7. *Spatial distribution of $C_6H_6^+$ m/z 78.0461 in San Antonio. Values are grid-cell means on a 500 m grid. Preliminary data (Figure credit: K. Kim UT Austin).*

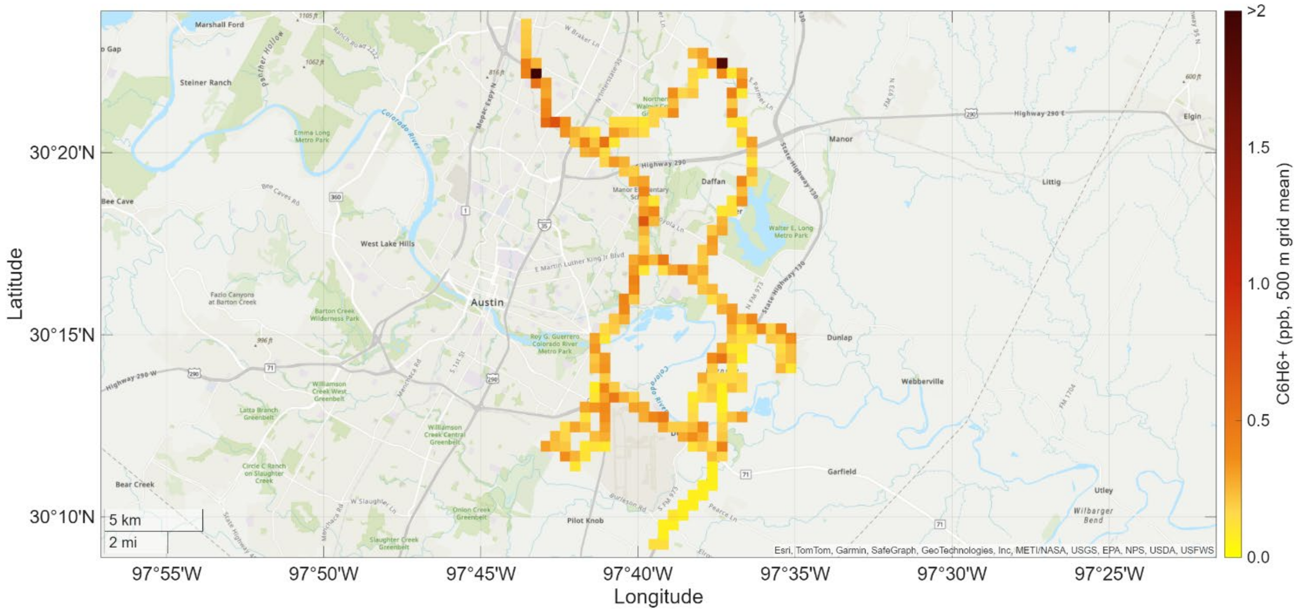
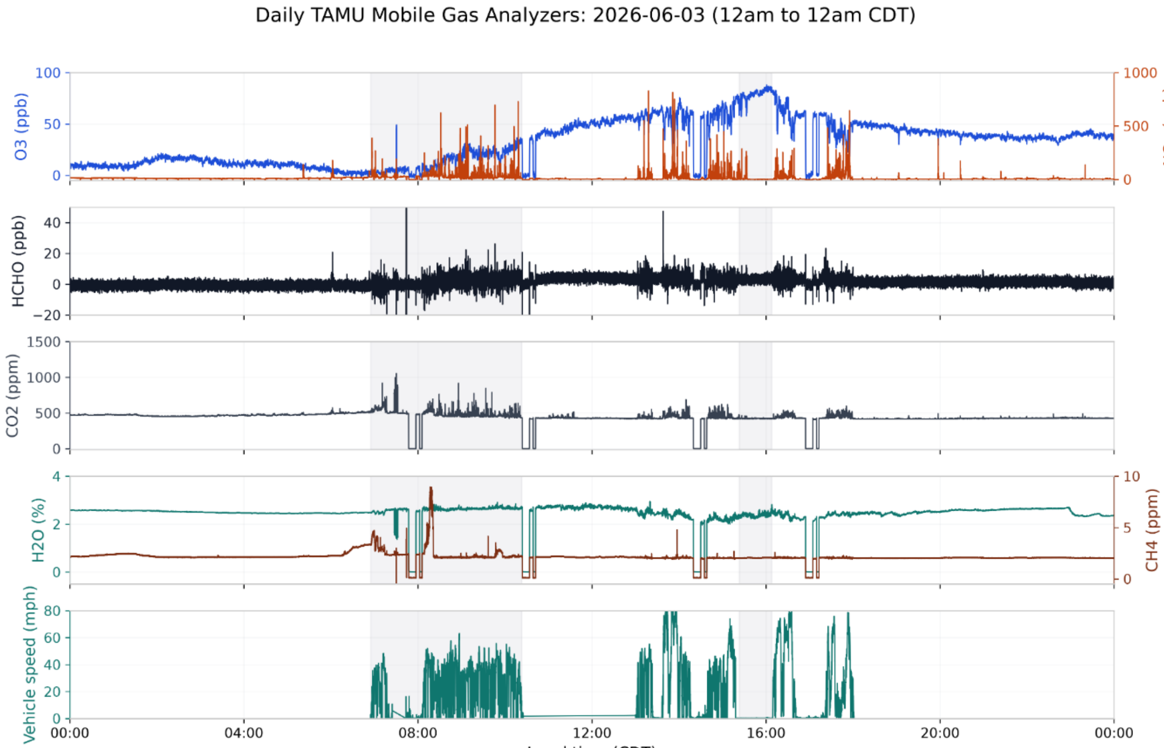


Figure 8. *Spatial distribution of* $C_6H_6^+$ *m/z 78.0461 in Austin. Values are grid-cell means on a 500 m grid. Preliminary data (Figure credit: K. Kim UT Austin).*

Overall, highest benzene concentrations were observed in Houston across the ship channel, Deer Park and other areas downwind of major sources, with 0.5 km grid averages occasionally exceeding 2 ppb, in particular in the Ship Channel. The highest benzene mixing ratio recorded in Houston by UT Austin van was 48.96 ppb at 10 s resolution, with a 99th percentile of 3.97 ppb. These values remain preliminary since the teams are still evaluating whether some of the sharpest plumes reflect nearby local sources rather than the larger facilities, and source attribution for the extremes is part of the ongoing analysis. The UT Austin and TAMU teams are collaboratively discussing the stories to be published and collaborations on source investigation and VCP and HAPs reporting to enhance inventory in collaboration with Nathan Malarich that may be useful for further TCEQ inventory enhancement.

Mobile Measurements (TAMU)

Figure 9 serves as an example of preliminary data of gas analyzers aboard the TAMU mobile lab beyond Vocus.



(Figure credit: J. Zhao).

Figure 9. *Daily summary of gas analyzers' readings. On June 3rd, the highest [O3] and [CH4] levels were recorded. The stepwise drops indicate the time when the team was simultaneously zeroing the instruments to find baseline values. The first shaded area represents the first route on that day, while the second shaded area corresponds to the stationary measurement at the Dallas spiral site.*

Stationary Measurements

Houston Supersite – Formaldehyde and TOF-AMS (UT Austin and TAMU)

UT Austin HR-ToF-AMS Preliminary Data

Figure 10 shows preliminary data from the high resolution time of flight aerosol mass spectrometer (HR-ToF-AMS), which measured non-refractory PM_1 (NR-PM_1), along with meteorological parameters. A University of Houston (UH) weather station measured temperature, relative humidity, and wind speed and direction from May 28-June 21, 2026 on the UH campus (29.716083, -95.329639). Solar irradiance and precipitation data were retrieved from Visual Crossing (Visual Crossing Corporation, 2026), along with temperature and relative humidity from May 26-May 28 at 16:20, before the UH weather station began measurements

The HR-ToF-AMS data were calibrated for ionization efficiency of nitrate (IE) and relative ionization efficiencies of sulfate and ammonium. The data were also corrected for airbeam and composition-dependent collection efficiency (CDCE) (Middlebrook et al., 2012). Interesting events are highlighted in purple in Figure 10. The campaign began with low temperatures on May 28th. Low temperatures favor formation of particle phase ammonium nitrate, which exists in equilibrium with gaseous ammonia and nitric acid in the atmosphere, and formation of organic aerosol via equilibrium partitioning (Seinfeld & Pandis, 2016). On June 3-6, it rained and we observe wet scavenging events that reduced NR-PM_1 concentrations, especially for the water-soluble species SO_4, NO_3, and NH_4. It rained again on June 15-17, with a tropical storm passing over Houston on June 17th. After the storm on June 18th, we measured high NR-PM_1 concentrations, especially SO_4 and NH_4. Based on HYSPLIT back trajectories (Rolph et al., 2017; Stein et al., 2015), this air mass traveled over the Gulf of America before approaching the site from the south.

Overall, wind direction was predominantly out of the southeast (Figure 11). The aerosol was acidic 70% of the time based on the ammonium balance method.

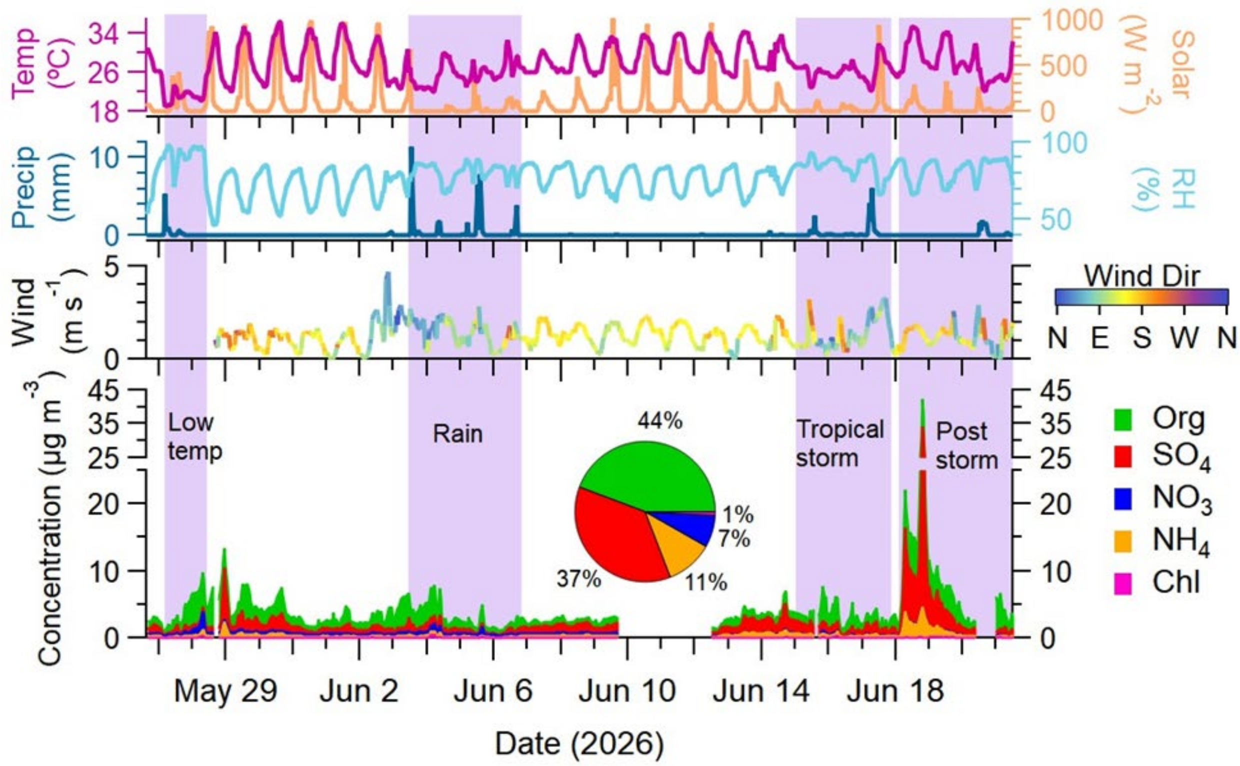


Figure 10. *Time series of NR-PM_1 measurements (µg m^{-3}) and meteorological parameters temperature (ºC), solar irradiance (W m^{-2}), relative humidity (%), precipitation (mm), and wind speed (m s^{-1}) colored by wind direction. The pie chart shows the campaign average percent composition for each bulk species. (Figure credit: Kat Konon; Data collected and processed by Chung-Ying Chao and Shihao Zhai)*

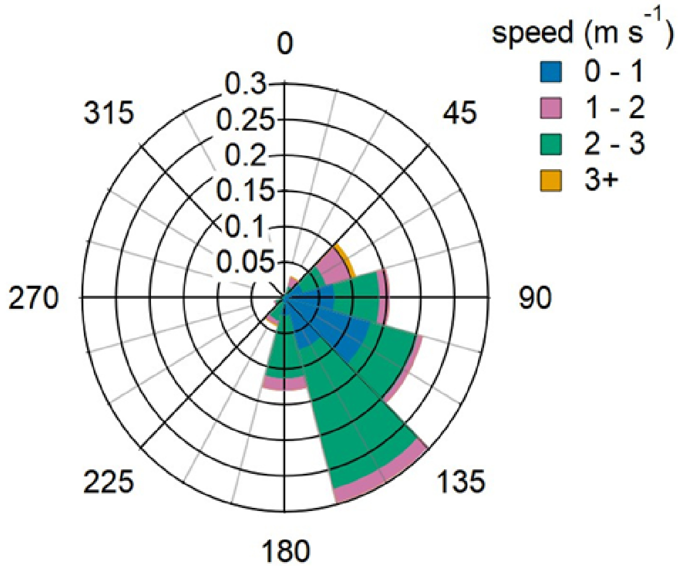


Figure 11. *Wind rose plot averaged over the course of the campaign. (Figure credit: Kat Konon)*

Texas A&M HR-ToF-AMS ($PM_{2.5}$) Preliminary Data

Figure 12 presents preliminary measurements of non-refractory PM2.5(NR-PM2.5) obtained using a TAMU high-resolution time-of-flight aerosol mass spectrometer (HR-ToF-AMS), together with NO_x, ozone, and meteorological parameters. Meteorological data with NO_x and ozone were obtained from the U.S. Environmental Protection Agency (EPA) website for a monitoring station (Houston East C1/G316) near the University of Houston. The measurements cover the period from 25 May to 21 June 2026.

The shaded periods in Figure 12 identify four meteorologically and chemically distinct episodes. The first period, from approximately 28 May to 2 June, was characterized by strong daytime ozone formation and large diurnal variability in temperature and relative humidity and is therefore identified as a regional ozone episode.

From approximately 3 to 4 June, a change in wind direction coincided with variations in NO_x, ozone, and NR-PM2.5 composition, suggesting the influence of an air mass transported from the Houston Ship Channel region. Rainfall occurring during 4-6 June was associated with lower aerosol concentrations, consistent with wet scavenging and enhanced atmospheric ventilation. The reductions were particularly evident for the water-soluble inorganic species sulfate, nitrate, and ammonium.

A second major precipitation period occurred during 15-17 June, when a tropical storm passed over Houston. During this period, high relative humidity and stronger, more variable winds were accompanied by generally lower and more variable NR-PM2.5 concentrations. Following the storm on 18 June, concentrations increased substantially, particularly for sulfate and ammonium.

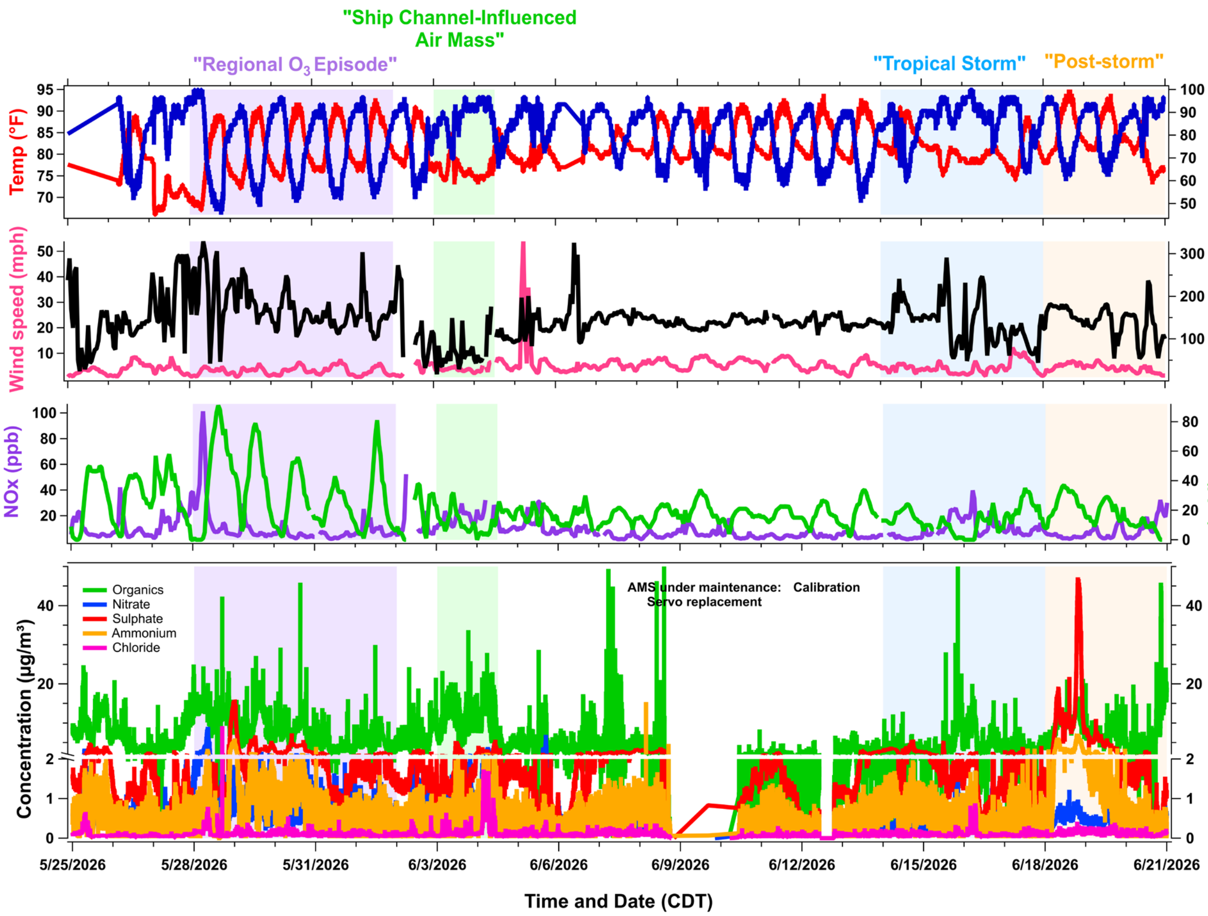


Figure 12. Time series of temperature, relative humidity, wind speed, wind direction, NO_x, ozone, and HR-ToF-AMS NR-PM2.5 components measured from 25 May to 21 June 2026. *(Figure credit: Rajab Mammadov, Yue Zhang's team)*

NOAA Aircraft and Other Preliminary Analyses (Nathan Malarich and Munkhbayar Baasandorj)

NOAA P3 aircraft equipped with a state-of-the art chemical payload flew over major urban areas in Texas between May 22 – June 16, 2026. Figure 13 provides an overview of the NOAA P3 flight paths, the urban areas, regions, and point sources surveyed. The flight map is overlayed with TEMPO NO_2 concentration map, where red indicates areas with elevated NO_2 concentrations. Houston and Dallas metropolitan areas were sampled 3 times, other urban areas once.

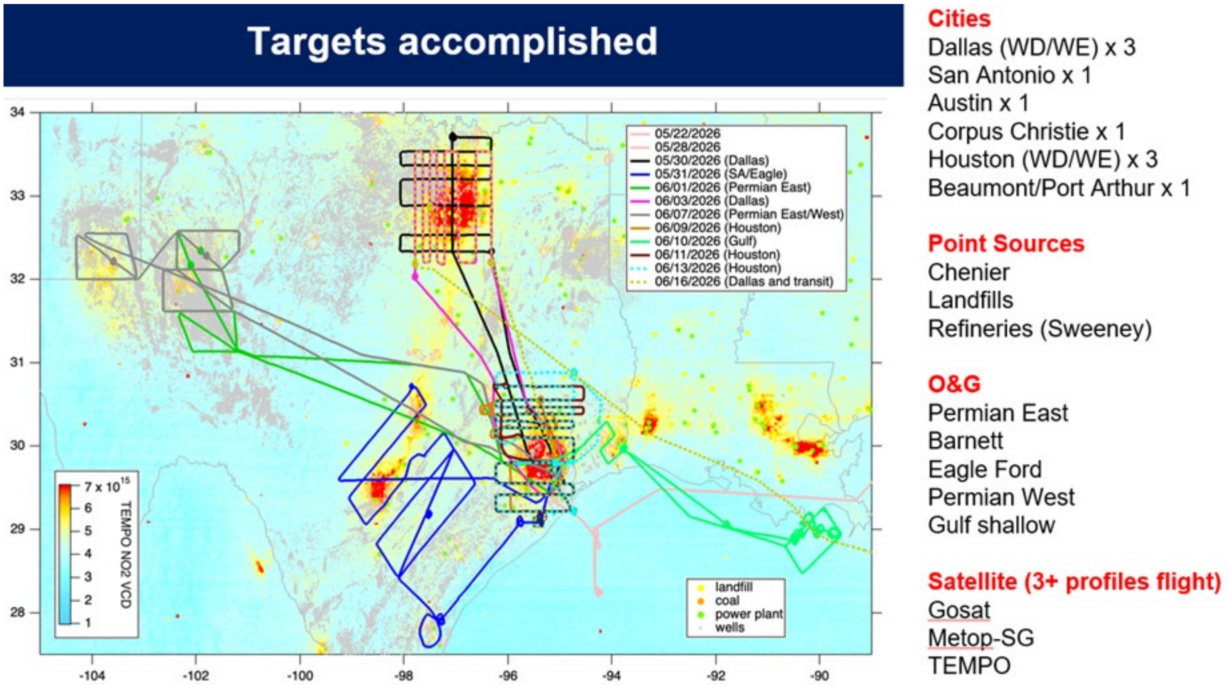


Figure 13. Map showing completed NOAA aircraft tracks.

Houston Supersite – NOAA PTR-MS coupled with Gas Chromatography (GC) (Munkhbayar Baasandorj, Yue Zhang, and NOAA)

- Speciated high-resolution Volatile Organic Compounds measurements at the Houston supersite, including instrument performance and preliminary time series.
- Periodic GC sampling allowed separation of isomers during the second half of the study.

Preliminary analysis

As part of TexAQS past and present analysis, Munkhbayar Baasandorj (UT) and Nate Malarich (CU Boulder) started integrating long-term observations of criteria pollutants and VOCs from TCEQ monitoring stations and comparing TexAQS observations. Figure 14 shows long-term air quality trends in Harris County with notable declines in primary air pollutants since 2000. TCEQ monitoring data indicates that the average ozone level declined approximately 30% and leveled off in 2015. Similarly, following more than 70% decline in average SO_2 levels, $PM_{2.5}$ trends show approximately 30% decline from 2000 to 2016. Annual $PM_{2.5}$ leveled off over last decade fluctuating just above the revised annual $PM_{2.5}$ NAAQS standard of 9.0 µg/m³. High-time resolution AMS measurements of the $PM_{2.5}$ composition conducted at the Houston super site will be important to understand the factors deriving $PM_{2.5}$ in Harris County.

Figure 15 compares O_3 levels observed over the Houston metropolitan area during TexAQS 2000 and TexAQS 2026. The aircraft captured enhancements in O_3 concentrations in urban outflow plumes originating from the Houston Ship Channel during both studies. The most notable difference is the scale of the concentration maps, with significantly lower O_3 concentrations observed in 2026. Different dates and timeframes should be noted due to strong seasonal variability in O3.

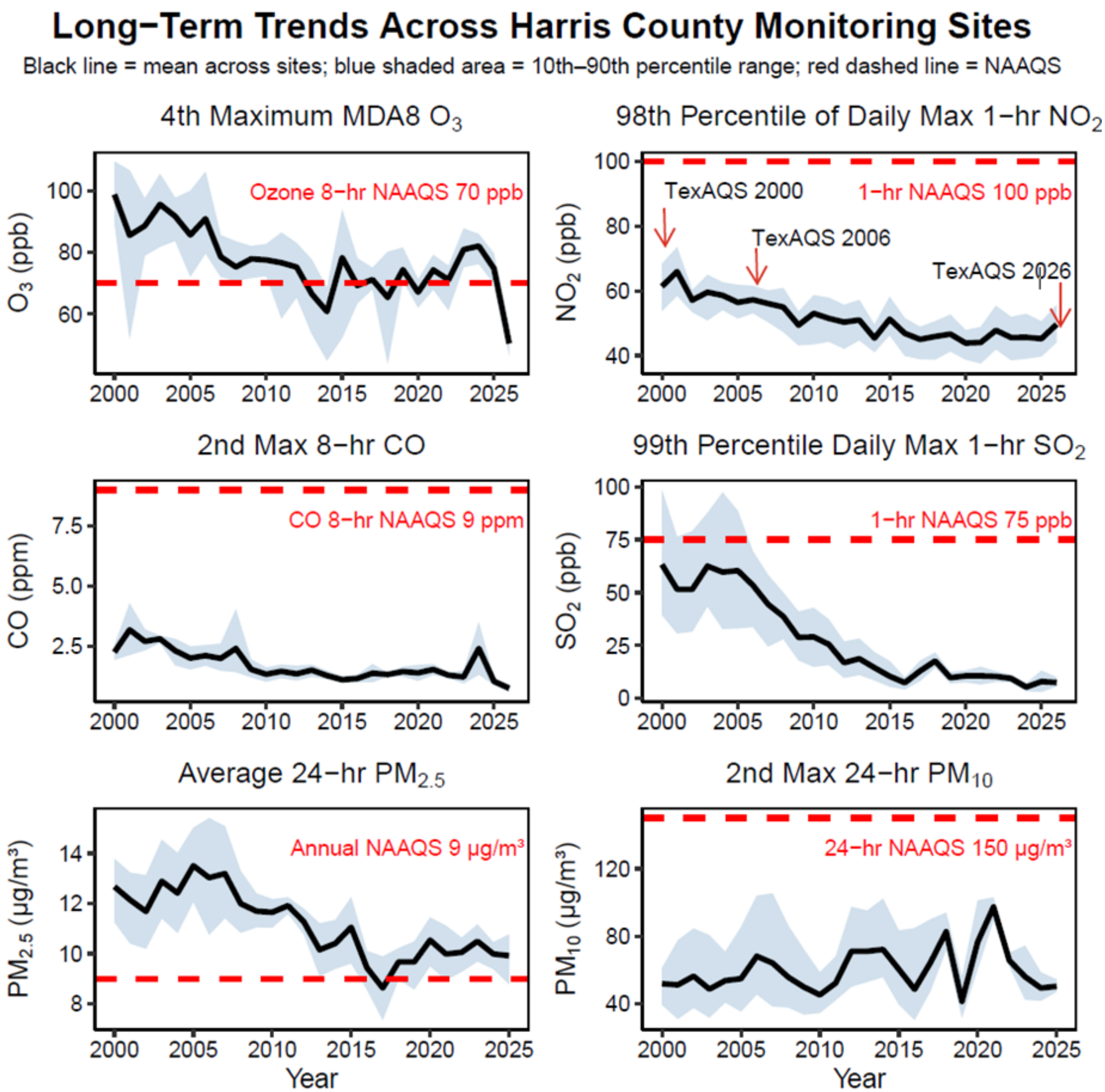


Figure 14. Long-term air quality trends in Harris County with notable declines in primary air pollutants since 2000.

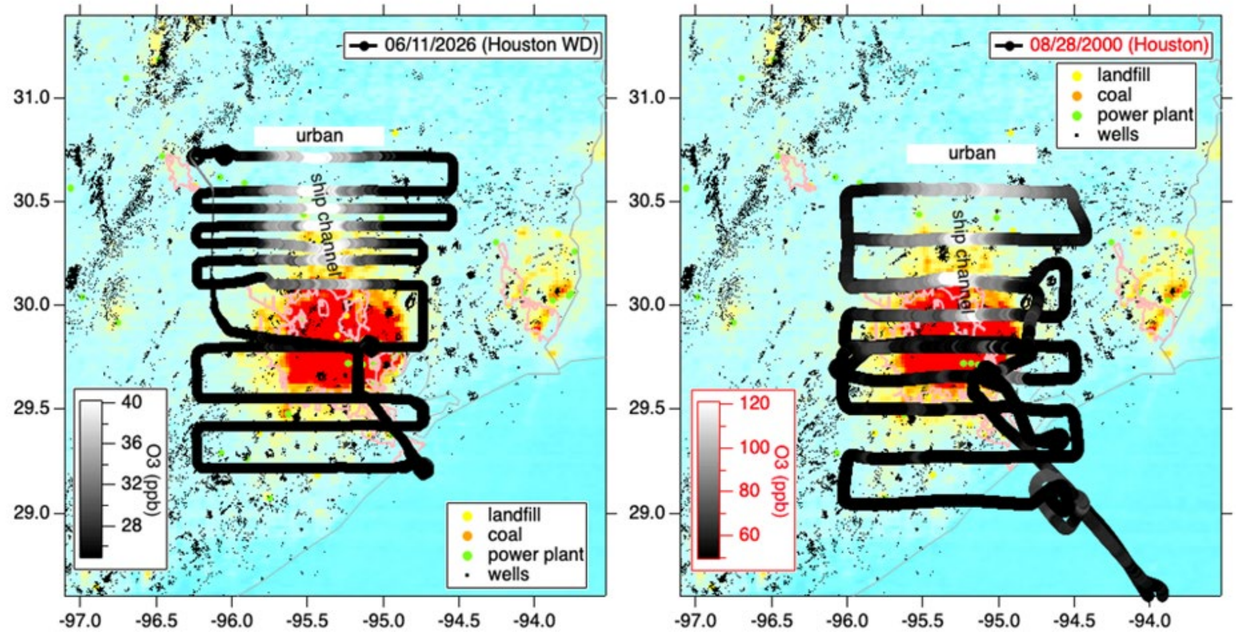


Figure 15. Comparison of O3 levels observed over the Houston metropolitan area during TexAQS 2000 (right) and TexAQS 2026 (left). TexAQS 2000 and 2026 were conducted in different months which may have contributed to the observed differences.

References

Coggon, M. M., Stockwell, C. E., Claflin, M. S., Pfannerstill, E. Y., Xu, L., Gilman, J. B., Marcantonio, J., Cao, C., Bates, K., Gkatzelis, G. I., Lamplugh, A., Katz, E. F., Arata, C., Apel, E. C., Hornbrook, R. S., Piel, F., Majluf, F., Blake, D. R., Wisthaler, A., Canagaratna, M., Lerner, B. M., Goldstein, A. H., Mak, J. E., and Warneke, C.: Identifying and correcting interferences to PTR-ToF-MS measurements of isoprene and other urban volatile organic compounds, Atmos. Meas. Tech., 17, 801–825, https://doi.org/10.5194/amt-17-801-2024, 2024.

Middlebrook, A. M., Bahreini, R., Jimenez, J. L., & Canagaratna, M. R. (2012). Evaluation of Composition-Dependent Collection Efficiencies for the Aerodyne Aerosol Mass Spectrometer using Field Data. *Aerosol Science and Technology*, *46*(3), 258–271. https://doi.org/10.1080/02786826.2011.620041

Rolph, G., Stein, A., & Stunder, B. (2017). Real-time Environmental Applications and Display sYstem: READY. *Environmental Modelling & Software*, *95*, 210–228. https://doi.org/10.1016/j.envsoft.2017.06.025

Seinfeld, J. H., & Pandis, S. N. (2016). *Atmospheric Chemistry and Physics: From Air Pollution to Climate Change, 3rd Edition | Wiley* (3rd ed.). Wiley.

Stein, A. F., Draxler, R. R., Rolph, G. D., Stunder, B. J. B., Cohen, M. D., & Ngan, F. (2015). NOAA's HYSPLIT Atmospheric Transport and Dispersion Modeling System. *Bulletin of the American Meteorological Society*, *96*(12), 2059–2077. https://doi.org/10.1175/BAMS-D-14-00110.1

US EPA. (2025, August 19). *National Ambient Air Quality Standards (NAAQS) for PM*. United States Environmental Protection Agency. Epa.Gov. https://www.epa.gov/pm-pollution/national-ambient-air-quality-standards-naaqs-pm

Visual Crossing Corporation. (2026). *Visual Crossing Weather*. Visual Crossing Weather. https://www.visualcrossing.com/weather-data/

Identify Any Problems or Issues Encountered and Proposed Solutions or Adjustments
None.

Goals and Anticipated Issues for the Succeeding Reporting Period
With the field phase complete, work in the succeeding period will focus on post-campaign data processing and analysis. Planned activities include quality assurance and quality control of the mobile records, mass calibration and background subtraction of the PTR-TOF-MS data, source apportionment (including PMF where appropriate), and intercomparison of the UT, TAMU, University of Houston, NOAA, and Houston supersite datasets. The team will consolidate route-density products and collocation logs for all four metropolitan areas and prepare data for delivery to TCEQ. BTEX compounds will be compared for the Dallas highest ozone day during the aircraft spiral. Doug Boyer (TCEQ) provided trace gas and VOC data from TCEQ monitoring stations which will be utilized in the analyses.

Detailed Analysis of the Progress of the Task Order to Date
The field campaign is complete and was executed on schedule. Mobile measurements were completed across all four target metropolitan areas (Dallas–Fort Worth, Houston, San Antonio, and Austin), with coordinated TAMU sampling, supersite operations in Houston, and NOAA P-3 aircraft collocations. The project has transitioned to the analysis phase, with data processing and intercomparison now underway.

Publications and Presentations

Do you have any publications related to this project currently under development? If so, please provide a working title, and the journals you plan to submit to.

☐ **Yes** ☒ **No**

Do you have any publications related to this project currently under review by a journal? If so, what is the working title and the journal name? Have you sent a copy of the article to your AQRP Project Manager and your TCEQ Liaison?

☐ **Yes** ☒ **No**

Do you have any bibliographic publications (ie: publications that cite the project) related to this project that have been published? If so, please list the reference information. List all items for the lifetime of the project.

☐ **Yes** ☒ **No**

Do you have any presentations related to this project currently under development? If so, please provide working title, and the conference you plan to present it (this does not include presentations for the AQRP Workshop).

☐ **Yes** ☒ **No**

Do you have any presentations related to this project that have been published? If so, please list reference information. List all items for the lifetime of the project.

☐ **Yes** ☒ **No**

Have any personnel changes occurred that were not listed in the original proposal? If so, please include a detailed description of the personnel change(s) below.

☐ **Yes** ☒ **No**

Are any delays expected in the progress of the research? If so, please include a detailed description of the potential delay below.

☐ **Yes** ☒ **No**

Describe any possible concerns/issues (technical or non-technical) that AQRP should be made aware of.

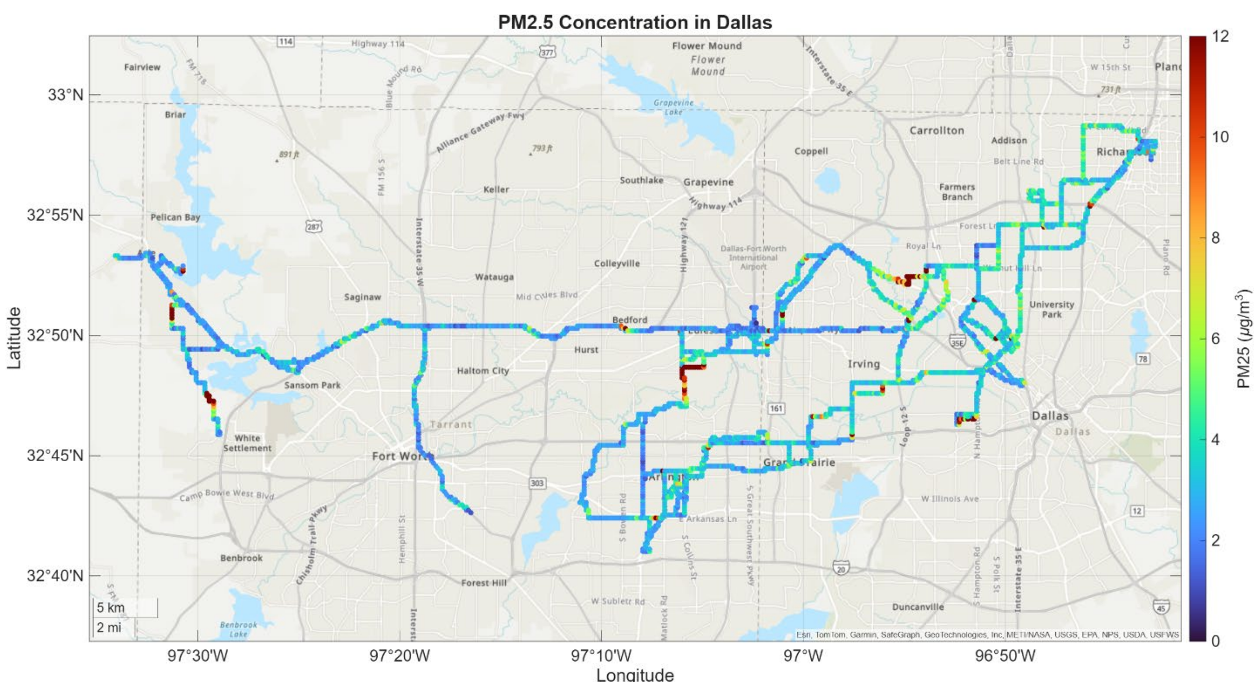
None

Are you anticipating using all the available funds allocated to this project by the end date? If not, why and approximately what is the amount to be returned?

☒ **Yes** ☐ **No**

Submitted to AQRP by
Pawel Misztal

Appendix: Other supplemental graphs or prelim analyses



Appendix Figure A. Example preliminary map of $PM_{2.5}$ from QuantAQ MODULAIR instrument. *Figure credit K. Kim UT Austin.*