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TRACER-MAP Field Campaign Report

RJ Sheesley
R Griffin
J Flynn
S Yoon
C-Y Chao
S Usenko
D Collins
Y Wang
K Sauceda
Z Zhu

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RJ Sheesley, Baylor University (BU)
Principal Investigator

S Usenko, BU
R Griffin, Roger Williams University
D Collins, University of California, Riverside (UCR)
J Flynn, University of Houston (UH)
Y Wang, UH
Co-Investigators

S Yoon, UH
K Sauceda, BU
C-Y Chao, Rice University
Z Zhu, UC-R
Additional team members

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Acronyms and Abbreviations

ACSM	aerosol chemical speciation monitor
AGL	above ground level
AMF	ARM Mobile Facility
AOS	Aerosol Observing System
APS	aerodynamic particle sizer
AQ2	Air Quality 2
ARM	Atmospheric Radiation Measurement
ASR	Atmospheric System Research
BU	Baylor University
CCNC	cloud condensation nuclei counter
CPC	condensation particle counter
DOE	U.S. Department of Energy
HR-ToF-AMS	high-resolution, time-of-flight, aerosol mass spectrometer
IOP	intensive operational period
MAQL	Mobile Air Quality Laboratory
NPF	new particle formation
NPFG	new particle formation and growth
RU	Rice University
SRI-PTRMS	selective reagent ionization-proton transfer reaction mass spectrometer
SMPS	scanning mobility particle sizer
TAP	tricolor absorption photometer
TCEQ	Texas Commission on Environmental Quality
TRACER	Tracking Aerosol Convection Interactions Experiment
UCR	University of California, Riverside
UH	University of Houston
UV	ultraviolet
VIS	visible spectrum
VOC	volatile organic compounds

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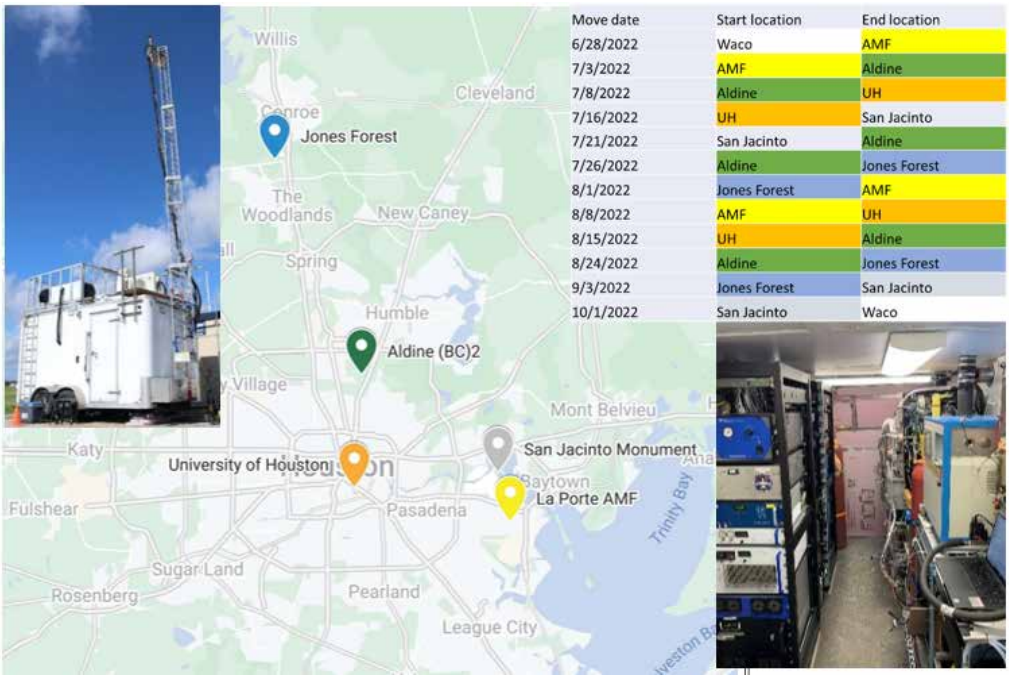
1.0 Summary

During July-August 2022, the U.S. Department of Energy (DOE) Atmospheric System Research (ASR)-funded Tracking Aerosol Convection Interactions Experiment (TRACER)-MAP campaign completed an Atmospheric Radiation Measurement (ARM) user facility field study to measure and map aerosol, volatile organic compounds (VOC), trace gas, and select meteorological observations across Houston, Texas. That ASR project and ARM field campaign, TRACER-MAP, was designed to complement measurements made at the first ARM Mobile Facility (AMF1) by the Aerosol Observing System (AOS) during the TRACER campaign. In this manner, TRACER-MAP effectively extended aerosol measurements from the TRACER AMF deployment, increasing the spatial coverage across the Houston metropolitan area, characterizing a greater diversity of source mixtures (e.g., industrial, traffic, residential, and biogenic) and capturing air masses with differential aging of urban source emissions (e.g., downtown versus downwind). That rich data set now offers many possibilities for in-depth analysis that align with the ASR mission to "research aerosol processes that affect Earth's radiative balance and hydrological cycle."

The TRACER-MAP project was aligned with the overall goals of TRACER: to investigate differences in aerosol and precursor gas parameters in pre- and post-convective storm scenarios. Thus, five sites were chosen to host the Baylor University (BU)-University of Houston (UH)-Rice University (RU)-University of California, Riverside (UCR) Mobile Air Quality Laboratory (MAQL2) for portable measurements (see inset Figure 1). TRACER-MAP made observations at each site two to three times through the course of July-August with the exception of San Jacinto, which had one visit during July with TRACER-MAP and then measurements running through the entire month of September with the MAQL2 under funding from the Texas Commission on Environmental Quality (TCEQ) for the TRACER-Air Quality 2 (AQ2) project. The Aldine site is a TCEQ site where TRACER-MAP operated with permissions from TCEQ.

Figure 3 has the full list of instrumentation in the MAQL2; the condensation particle counter (CPC), aerodynamic particle sizer (APS), scanning mobility particle sizer (SMPS), nephelometer, and tricolor absorption photometers (TAPs) align with similar instrumentation in the AOS, while the high-resolution, time-of-flight, aerosol mass spectrometer (HR-ToF-AMS) provides additional size-resolved aerosol composition beyond the aerosol chemical speciation monitor (ACSM) available in the AOS. TRACER-MAP had a more extensive gas-phase instrumentation list: in particular, VOCs by selective reagent ionization-proton transfer reaction mass spectrometer (SRI-PTR-MS) were specific to the MAQL2. The similarity of the instrument list between the AOS at La Porte and TRACER-MAP can be exploited for additional studies and integration of models with observations across the Houston domain.



Move date	Start location	End location
6/28/2022	Waco	AMF
7/3/2022	AMF	Aldine
7/8/2022	Aldine	UH
7/16/2022	UH	San Jacinto
7/21/2022	San Jacinto	Aldine
7/26/2022	Aldine	Jones Forest
8/1/2022	Jones Forest	AMF
8/8/2022	AMF	UH
8/15/2022	UH	Aldine
8/24/2022	Aldine	Jones Forest
9/3/2022	Jones Forest	San Jacinto
10/1/2022	San Jacinto	Waco

Figure 1. Aerosol, VOC, and trace gas observations were made with instrumentation in the BU-UH-RU-UCR Mobile Air Quality Laboratory (MAQL2, insets), which moved among five locations during the TRACER intensive operational period (IOP). Locations and duration of sampling at each site during TRACER-MAP (July 1-August 31) and TRACER-AQ (September 1-30) as listed in the table inset. TRACER-MAP was an ARM field campaign funded by ASR, while TRACER-AQ continued with select instrumentation at San Jacinto during September and was funded by the Texas Commission on Environmental Quality.

Aerosol	Gas	Met/atmospheric
Aerodyne high-resolution time-of-flight aerosol mass spectrometer (**HR-ToF-AMS**),	**CO** instrument (off-axis integrated cavity output spectroscopy)	Ceilometer (Vaisala CL-31)
Brechtel tricolor absorption photometers (**TAPs**, 365, 520, and 640 nm)	**SO_2** instrument with a pulsed fluorescence analyzer (Thermo Environmental, Inc., Model 43i-TL).	RM Young 86000 ultrasonic anemometer
TSI 3563 **nephelometer** (for 450, 550, and 700 nm)	**O_3** by Thermo Environmental, Inc., Model 42C monitor that has been modified to measure O_3 via chemiluminescence (CL) with NO	RM Young 41382 temperature and relative humidity probe
Scanning Mobility Particle Sizer (**SMPS**)	**NO and NO_2** by Air Quality Designs, Inc., high-sensitivity NO_x instrument	61302V barometric pressure sensor
Cloud Condensation Nuclei Counter (**CCNc**)	**Total NOy** by Molybdenum oxide catalytic converter and subsequent CL (Thermo Environmental, Inc., Model 42i)	Meterologie Consult, GmbH filter radiometer for j_{NO2}
Aerodynamic Particle Sizer (**APS**)	**VOCs** using a selective reagent ion - proton transfer reaction mass spectrometer (SRI-PTR-MS, Ionicon)	
Condensation Particle Counter (**CPC**)		

Figure 2. List of measurements during TRACER-MAP. The SMPS, CCNC, APS, and CPC were not run during TRACER-AQ.

2.0 Results

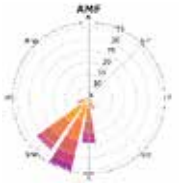
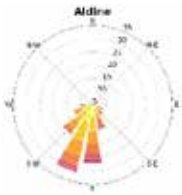
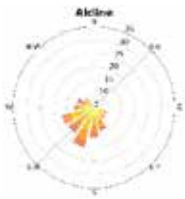
TRACER-MAP sites enable case studies for different background conditions. Each site during TRACER-MAP was chosen to represent different emission scenarios and background conditions within the Houston domain. For example, in July, the AMF site primarily experienced south-southwesterly flow, while wind direction was more variable in August (Table 1). This experimental design will allow for improved overall understanding and characterization of aerosol processes during TRACER and will be useful for broader studies of cloud-aerosol interactions in the Houston domain. Brief descriptions of the background conditions at each site are provided below. As each site visit lasted roughly 5-7 days, each of these visits can be considered as different experimental scenarios for aerosol process analysis. However, all these scenarios are in the greater Houston domain and relevant to the larger TRACER project and to understanding new particle formation and growth (NPFG) in urban areas.

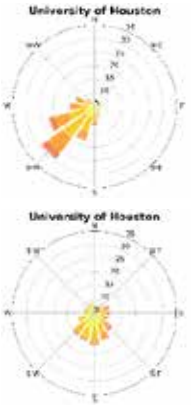
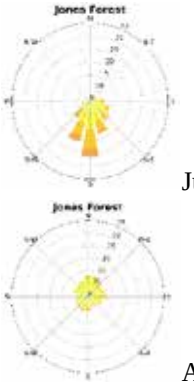
La Porte AMF and San Jacinto Battleground: Southerly flow at San Jacinto will allow for evaluation of small-scale processing between the AOS observations at AMF and San Jacinto. In terms of background conditions for new particle formation (NPF), San Jacinto experienced high concentrations of precursor emissions during the TRACER-MAP campaign: for example, aromatic VOCs, SO_2, and NO_x, had lower aerosol concentrations for non-refractory components than other sites. Between July and August, the AMF site had a shift in composition: for example, VOCs composition shifted towards a greater fraction of alkyl benzenes (e.g., C2, C3, and C4 benzenes) in August.

Aldine and University of Houston (UH): Aldine and UH were visited multiple times during TRACER-MAP, with a change in non-refractory aerosol composition from dominance of sulfate to organics from July to August. In addition, both sites experienced changes in the background concentrations and diurnal variability of precursor gases over the July and August observations.

Jones Forest: This site experiences higher influence from biogenic sources, but also is also often exposed to transported aged air masses. These background conditions are evident in the observations, which include greater influence from biogenic VOCs and oxidized VOCs than the other Houston sites, while the aerosol composition again shifts from sulfate to organic dominance from July to August.

Table 1. TRACER-MAP sites with a description of the local land use, co-located instrumentation associated with other networks, and the dominant wind direction during the MAQL2 deployments.

TRACER-MAP Site	Land Use	Co-located Instrumentation	Wind Direction
La Porte AMF	The site is located at an airport, due south of the industrial area (<4 km) along the Houston Shipping Channel and due north of the Baytown refinery and port. The surrounding land use is otherwise residential.	AMF1 with Aerosol Observing System, additional guest instrumentation associated with other ARM and ASR projects.	 July  Aug
San Jacinto Battleground	The site is located north of the industrial park in Deer Park, ~9.6 km north-northwest of the AMF site. The surrounding land use is the Houston Ship Channel, which includes Port Houston, the largest Gulf Coast container port and tanker terminals, and the largest related industrial facilities in the U.S. by water tonnage.		 July
Aldine	The site is located 16 km north-northeast of downtown Houston, near Interstate-69. The surrounding land use is primarily commercial and residential.	BU and UH operate the BC2 aerosol optical network, which has filter-based aerosol absorption, aerosol scattering, $PM_{2.5}$ filter sampling, and CO. TCEQ also monitors $PM_{2.5}$, ozone, and NO_X.	 July  Aug

TRACER-MAP Site	Land Use	Co-located Instrumentation	Wind Direction
University of Houston	The site is located ~ 5km southeast of downtown Houston, along Interstate-45. The surrounding land use is commercial, industrial, railyard, and residential (east and southeast).	The launch trailer (ground site) measures O_3, NO, NO_X, NO_Y, CO, gas columns, boundary-layer height, and meteorological parameters. Moody Tower (60 m AGL) measures O_3, NO, NO_X, NO_Y, CO, SO_2, meteorological parameters, aerosol optical depth, O_3 column, and UV and visible spectrum (VIS) shadowband radiometers.	 July Aug
Jones Forest	The site is located 54 km north-northwest of downtown Houston in the WG Jones State Forest. It is south of the Sam Houston National Forest, a mixed pine-hardwood forest dominated by Loblolly pines. The surrounding land use is urban forest and residential.	UH operates an HNET site at Jones Forest and measures O_3, CO, and meteorological parameters.	 July Aug

*The wind speed scale runs from 0 to >10 for yellow to indigo.

For the measurement data of each instrument, we have included below a time series to visualize the data variability across the domain during TRACER-MAP.

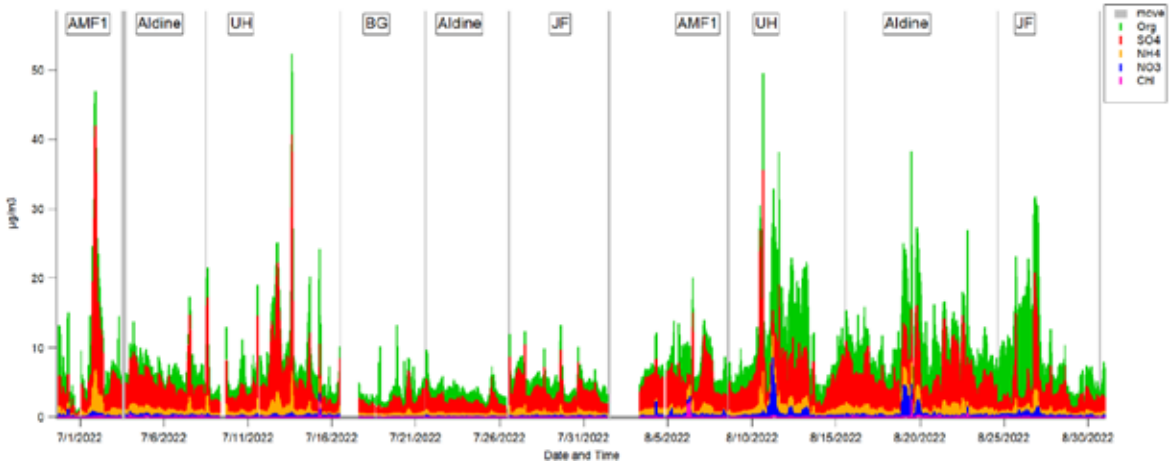


Figure 3. Time series of aerosol composition from the HR-ToF-AMS for July-August 2022 during the TRACER-MAP IOP. The sampling locations are noted above the time series.

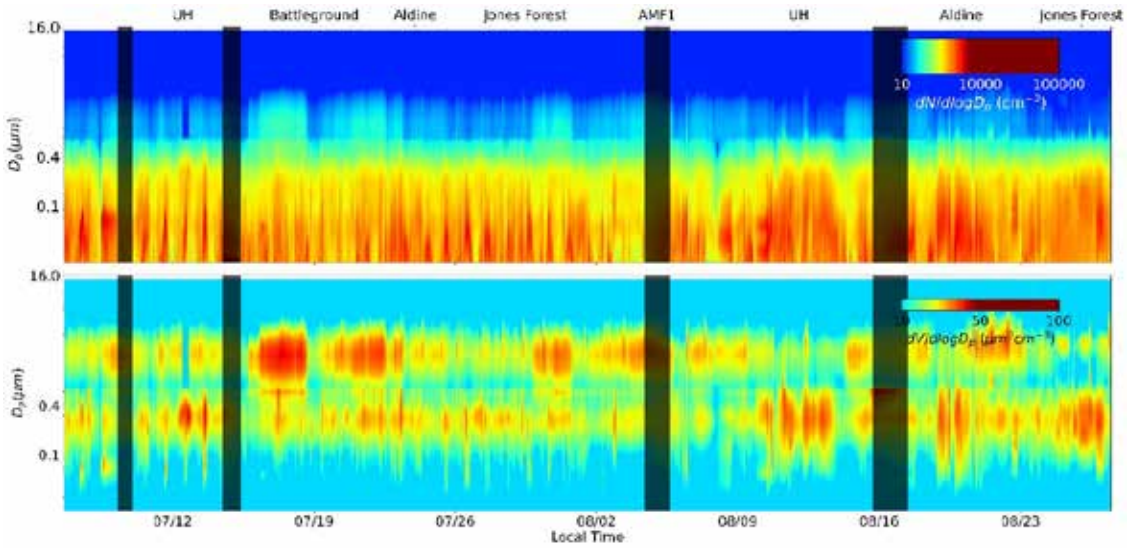


Figure 4. Time series of the preliminary particle number and size measurements for July-August 2022 during the TRACER-MAP IOP. The sampling locations are indicated in text above the figure.

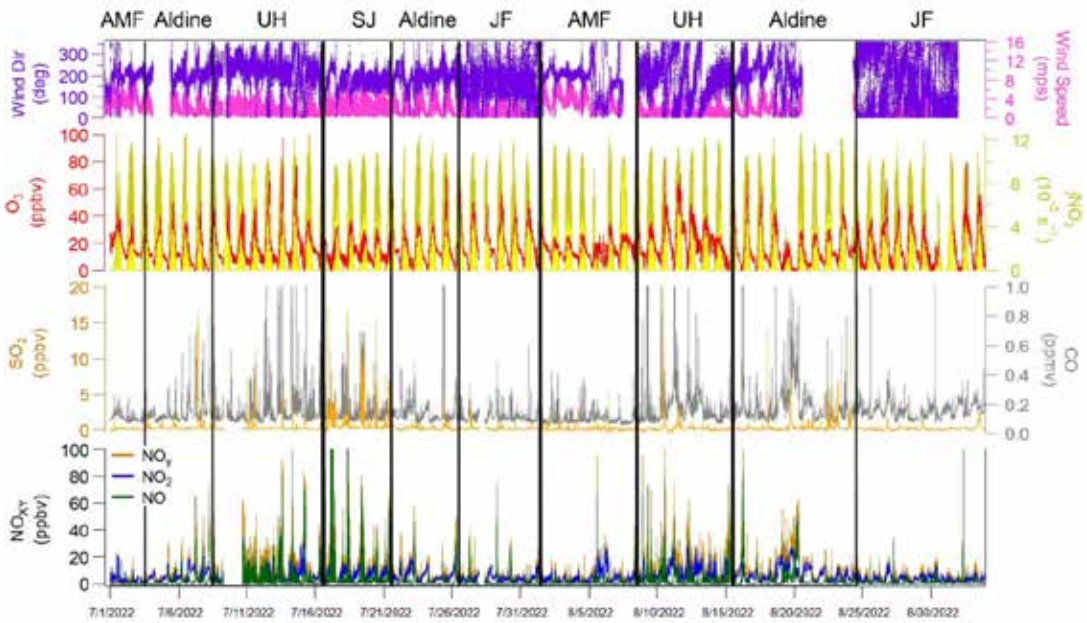


Figure 5. Time series of meteorological data and trace gas mixing ratios for July-August 2022 during the TRACER-MAP IOP. The sampling locations are indicated in text above the figure.

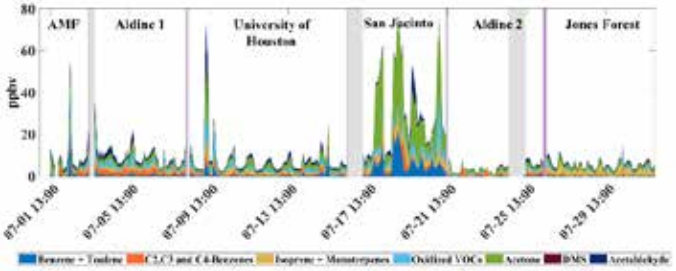


Figure 6. Time series of volatile organic compound data from the PTRMS for July 2022 during the TRACER-MAP IOP. The sampling locations are indicated in text above the figure.

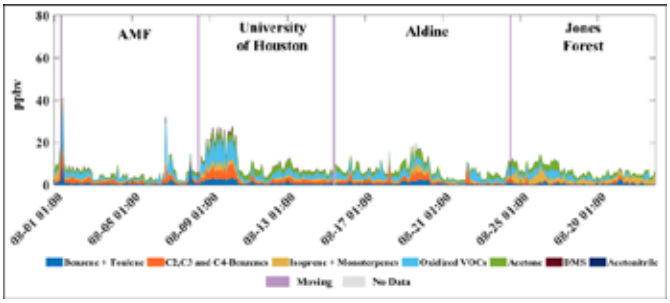


Figure 7. Time series of volatile organic compound data from the PTRMS for August 2022 during the TRACER-MAP IOP. The sampling locations are indicated in text above the figure.

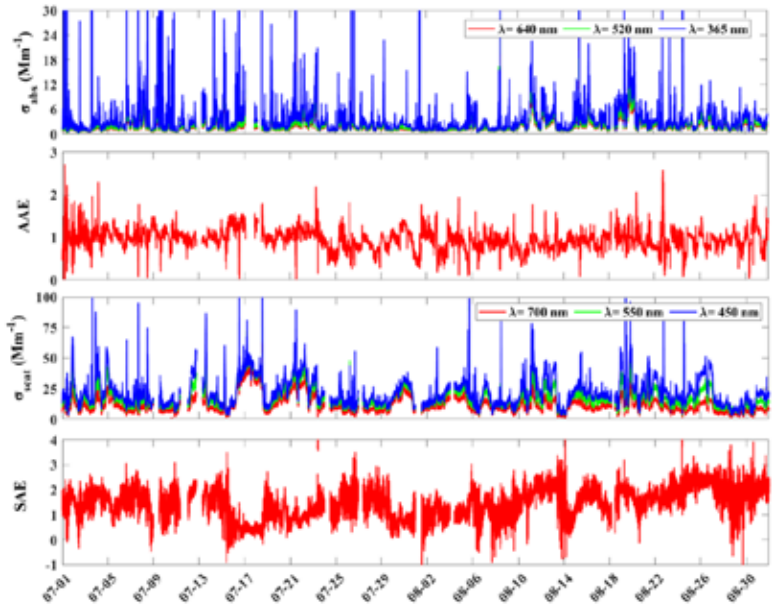


Figure 8. Time series of aerosol optical properties for July-August 2022 during the TRACER-MAP IOP. The aerosol absorption was measured using a TAP while the scattering was measured using a TSI nephelometer.

3.0 Publications and References

Sauceda, KA, R Sheesley, S Shrestha, S Usenko, R Griffin, C-Y Chao, D Collins, Z Zhu,Y Wang, J Flynn, S Yoon, F Guo, and S Zhou. 2023. “TRACER-MAP: a preliminary look at the changes in VOC composition and aerosol optical properties before and after precipitation events in Houston.” Poster presented at the American Meteorological Society Annual Meeting. (Sauceda tied for second place in the student poster competition.)

4.0 Lessons Learned

Preliminary data suggest that, based on the overall scientific goals, the field component of TRACER-MAP will help investigation of the regional variability across the AMF1 domain and improve contextualization of AMF1 observations, specifically strategic characterization of spatial and temporal variability during the TRACER-IOP.

The strength of TRACER-MAP was two-fold: 1) the MAQL2 is a self-contained mobile aerosol platform that during TRACER-MAP was successfully deployed independently across the AMF1 domain, and 2) the MAQL2 instrumentation matched or enhanced aerosol and trace gas aerosol precursors measurements at AMF1.

The decision to postpone TRACER by approximately one year was inherently difficult and fraught with unknown consequences. Nevertheless, it ultimately proved to be the best decision for the circumstances, as it enabled researchers to concentrate on the science without being preoccupied with COVID-19, their personal health, and that of their friends and colleagues.

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