TRACER-MAP Field Campaign Report

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March 2023
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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.
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.

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<th>Move date</th>
<th>Start location</th>
<th>End location</th>
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<tbody>
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<td>Aldine</td>
<td>Ull</td>
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<td>7/16/2022</td>
<td>Ull</td>
<td>San Jacinto</td>
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<td>Aldine</td>
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</tr>
<tr>
<td>10/3/2022</td>
<td>San Jacinto</td>
<td>Waco</td>
</tr>
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</table>

**Figure 1.** 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., C$_2$, C$_3$, and C$_4$ 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.

<table>
<thead>
<tr>
<th>TRACER-MAP Site</th>
<th>Land Use</th>
<th>Co-located Instrumentation</th>
<th>Wind Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>La Porte AMF</td>
<td>The site is located at an airport, due south of the industrial area (&lt;4 km) along the Houston Shipping Channel and due north of the Baytown refinery and port. The surrounding land use is otherwise residential.</td>
<td>AMF1 with Aerosol Observing System, additional guest instrumentation associated with other ARM and ASR projects.</td>
<td>July</td>
</tr>
<tr>
<td>San Jacinto Battleground</td>
<td>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.</td>
<td></td>
<td>July</td>
</tr>
<tr>
<td>Aldine</td>
<td>The site is located 16 km north-northeast of downtown Houston, near Interstate-69. The surrounding land use is primarily commercial and residential.</td>
<td>BU and UH operate the BC2 aerosol optical network, which has filter-based aerosol absorption, aerosol scattering, PM$<em>{2.5}$ filter sampling, and CO. TCEQ also monitors PM$</em>{2.5}$, ozone, and NO$_x$.</td>
<td>July, Aug</td>
</tr>
</tbody>
</table>
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.

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

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**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


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.