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Texas A&M University Mobile Facility Measurements during TRACER Field Campaign Report

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May 2023

ARM

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Acronyms and Abbreviations

AMF	ARM Mobile Facility
ANC	ancillary site
ARM	Atmospheric Radiation Measurement
CAPE	convective available potential energy
CCN	cloud condensation nuclei
CCNC	cloud condensation nuclei counter
CIN	convective inhibition
CPC	condensation particle counter
DOE	U.S. Department of Energy
DRUM	Davis Rotating Uniform size-cut Monitor
GPS	Global Positioning System
INP	ice nucleating particle
IOP	intensive operational period
MPL	micropulse lidar
POPS	portable optical particle spectrometer
ROAM-V	Rapid Onsite Atmospheric Measurement Van
SBF	sea-breeze front
SMPS	scanning mobility particle sizer
TAMU	Texas A&M University
TRACER	Tracking Aerosol Convection Interactions Experiment
UAS	uncrewed aerial system
UTC	Coordinated Universal Time

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1.0 Summary

One of the main goals of the U.S Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) Tracking Aerosol Convection Interactions Experiment (TRACER) near Houston, Texas is to improve understanding of how meteorology and aerosols impact storm dynamical and microphysical processes in deep convection to better constrain and improve their model representation. The Houston area is strongly influenced by sea- and bay-breeze circulations that generate convergence and help to initiate and organize deep convection. To properly isolate and understand the roles of varied meteorological conditions and cloud condensation nuclei (CCN) and ice nucleation particles (INP) distributions in different air masses, co-located thermodynamic, kinematic, and aerosol vertical profile observations are needed. The focus of this campaign was to provide key measurements in air masses both in front of and behind sea/bay breeze fronts moving through the greater Houston area to sample the airmass heterogeneity. The overarching scientific goal of this campaign is to understand how the vertical distributions of both CCN and INP correspond to the inflow layer of deep convection in maritime, background continental, and polluted continental air masses, and how these variations influence deep convection.

To fully sample the heterogeneity in both meteorological conditions and aerosols across the sea-breeze front (SBF), Texas A&M University (TAMU) deployed a InterMet 3050A 403 MHz mobile unit launching iMet-4 radiosondes and the new Rapid Onsite Atmospheric Measurement Van (ROAM-V) for aerosol sampling during the TRACER intensive operational period (IOP) from June to September 2022. The suite of instruments deployed on ROAM-V included a condensation particle counter (CPC; GRIMM Model 5.403 CPC), scanning mobility particle sizer (SMPS; TSI 3750 detector, TSI 3082 classifier, TSI 3088 neutralizer, TSI 3081A differential mobility analyzer), cloud condensation nuclei counter (Droplet Measurement Technologies CCN counter), micropulse lidar (Droplet Measurement Technologies micropulse lidar [miniMPL]), and a Davis Rotating Uniform size-cut Monitor (DRUM; DRUMAir 4-DRUM). Before sampling at each location, the latitude and longitude were recorded using the Global Positioning System (GPS) on the phone application “My Altitude”. The DRUM data were collected as part of a closely related ARM field campaign and also supported by DOE Atmospheric System Research grant DE-SC0021047.

The TAMU team sampled these airmass heterogeneities by strategically choosing deployment sites in a different airmass than the ARM fixed sites in La Porte and Guy, Texas. On days when the sea/bay breeze boundary was pushing inland, the TAMU team would usually sample the airmass on the maritime side of the SBF at a coastal site in Galveston, Texas in the early afternoon (1730-1900 UTC) and then move inland ahead of the SBF to sample the airmass on the continental side during late afternoon (2030-2230). Figure 1 shows the Galveston maritime site and the array of sites for the late afternoon continental measurements.

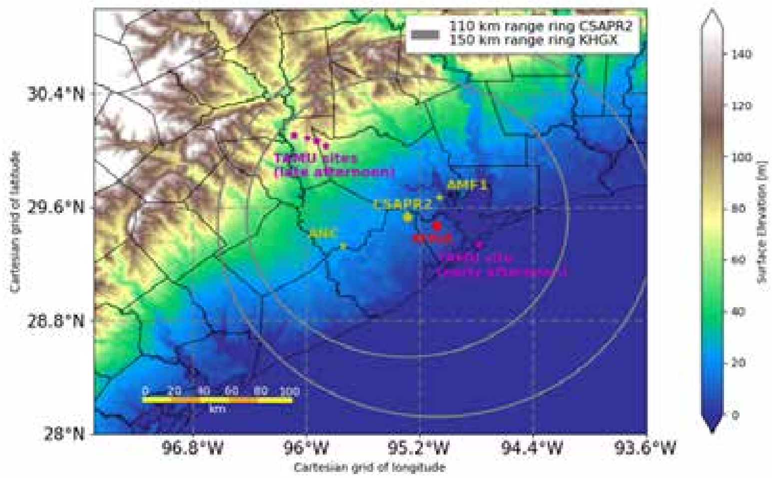

Figure 1. TAMU TRACER deployment sites.

ROAM-V began sampling as soon as we arrived at each site (~1-1.5 hour prior to radiosonde launch). Soundings were launched simultaneously with radiosondes at the ARM sites on a subset of the rapid sounding operations/radar cell tracking days during the June-September, 2022 IOP. Any deviations from our standard sampling strategy were necessitated by external factors such as widespread convective coverage requiring an earlier launch or mixing of SBF with convective outflow resulting in faster-moving boundaries mandating the selection of a site and collecting measurements from the same site before and after the sea breeze crossed the site.

The subset of enhanced IOP days that TAMU TRACER operated is listed in Table 1. Due to delivery delays of ROAM-V, the first seven deployments in June and early July were radiosonde-only. There were a total of 29 sounding IOPs, including 22 joint with aerosol measurements sampling a variety of airmasses including maritime, continental, convective outflow and recovery, and post-frontal. We also deployed ROAM-V for 10 aerosol-only deployments on non-enhanced IOP days for background air samples, comparisons with ARM instruments, and joint deployments with the TRACER-uncrewed aerial system (UAS) team for lidar-portable optical particle spectrometer (POPS) profile comparisons that will be used to improve our planned vertical aerosol profile retrievals. All sounding and aerosol data collected during the TAMU TRACER IOPs have been uploaded to the ARM Data Center. All ice nucleation data from the ROAM-V deployment have been submitted with the ice nucleation data associated with our other report, Ice Nucleation, Measurements during TRACER Field Campaign Report (DOE/SC-ARM-23-022).

Table 1. TAMU TRACER deployment summary. Instrument deployed are indicated in color.

	Deployment type	**Date of deployment type/locations**
Total number of IOP days	22 joint radiosonde/aerosol 7 radiosonde only 10 aerosol only	June 2, 21, 22, 26, 29 July 6, 11, 12, 13, 27, 28, 29, 30, 20, 22, 26 August 7, 8, 9, 10, 21, 22, 26, 27, 28, 31, 23, 24 September 6, 7, 17, 18, 19, 25, 1, 20, 21, 22, 23
Type of airmass sampled	Continental – 12 Maritime – 16 Convective outflow – 6 Outflow recovery – 3 Post frontal – 1	Continental – Multiple sites in NW Houston Maritime – Seawolf Park, Galveston

2.0 Results

An example of a subset of radiosonde and ROAM-V measurements during a single early afternoon deployment at Galveston on 13 July 2022 is shown in Figure 2 below. There is evidence of the sea-breeze front crossing Galveston just after noon local time as evidenced by the wind shift measured with our surface weather station. It is also evident in the ROAM-V MPL backscatter as the cleaner maritime air moves inland and the aerosol layer gets pushed above the SBF. The sounding from that day shows an atmosphere with very high convective available potential energy (CAPE) and almost no convective inhibition (CIN).

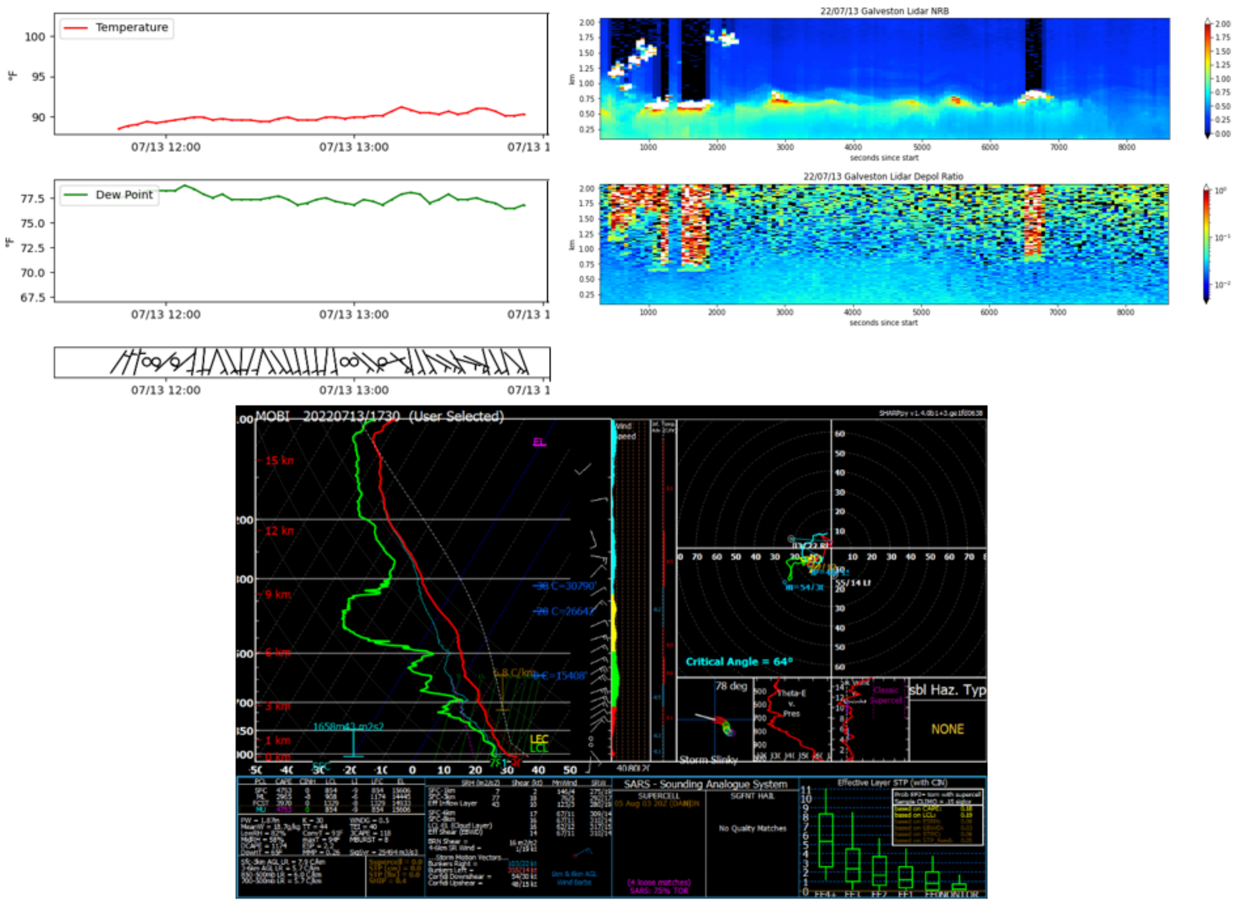

Figure 2. (top left panels) Surface weather station temperature, humidity, and winds, (top right panels) MPL backscatter and depolarization ratio, and (bottom left) iMet-4 radiosonde temperature, dewpoint, winds, and various convective potential indices from TAMU TRACER deployment at Seawolf Park, Galveston, Texas, on 13 July 2022.

Composite sounding and aerosol concentrations from deployment days with sea breeze-initiated convection are shown in Figure 3. The early afternoon maritime airmass shows significantly more mixed-layer CAPE than the continental airmass, despite much higher afternoon surface temperatures in the continental airmass. Unsurprisingly, the aerosol size distributions from the SMPS instrument show higher peak concentrations in the continental airmass, although the maritime airmass has significantly higher concentrations than we expected. There is a notable shift in the sizes when the number concentrations peak. In the maritime airmass, sizes are smaller at higher concentrations while the opposite occurs in the continental airmass.

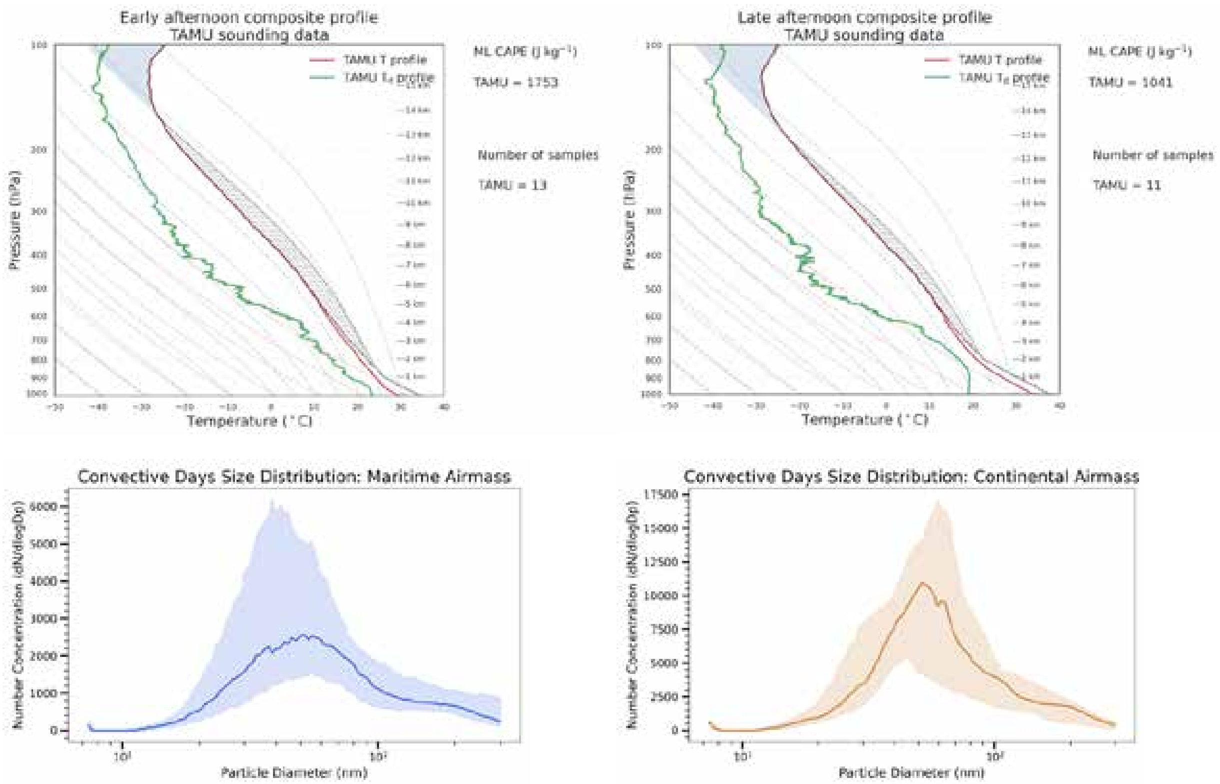

Figure 3. (top row) Composite soundings and (bottom row) aerosol size distributions for the (left column) early afternoon maritime airmass deployment and the (right column) late afternoon continental airmass deployment.

Some surprising results from the campaign may also be explored by us and other investigators. Based on our prior observations, we hypothesized that the CAPE would be higher and environments more conducive to deep convection in the continental airmass; however, our measurements show the opposite. This suggests that moisture modulates the CAPE more than temperature, but it is unclear if this finding can be generalized for sea-breeze airmasses along the Gulf Coast or if this was a particularly dry year with a more moisture-limited environment than is typical.

We also found a surprisingly dirty maritime airmass with high aerosol number concentrations with low CCN activity in the post-sea breeze airmass at Galveston. It is unclear whether Galveston Island is too heavily influenced by the ship channel or whether it is also possible that the land breeze circulation carries the high aerosol concentration air off the Houston urban and industrial regions out over the Gulf of Mexico at night, and then the sea breeze recirculates that polluted air back toward the coast during the day. In the continental airmass, we found significant variations in aerosol concentrations and CCN activity over very small spatial scales (not shown), highlighting the extreme heterogeneity in the Houston region.

Our team plans to use these data in conjunction with the first ARM Mobile Facility (AMF1) and ancillary site (ANC) data:

- to understand horizontal, vertical, and temporal variability of temperature, moisture, winds, and aerosols (specifically potential CCN and INP) in the Houston region, particularly relative to sea/bay-breeze front
- to develop vertical profile retrievals of CCN and INP to understand how vertical distributions of CCN and INPs vary within the inflow layer of convection in different air masses in the Houston region
- to understand how updraft and convection characteristics vary with aerosols and meteorological environments across the SBF
- as input to idealized numerical simulations to determine the separate influence of meteorological conditions and aerosols on convection processes and characteristics.

Beyond our planned further research, these data may also be used to improve understanding of the sea breeze dynamics, how thunderstorm outflow impacts meteorological and aerosol environments, aerosol heterogeneity across the Houston region, and a variety of other topics.

3.0 Publications, Presentations, and References

3.1 Oral Presentations

Sharma, M, AD Rapp, and CJ Nowotarski. 2023. “Thermodynamic Variability across Sea-Breeze Fronts and Thunderstorm Updraft Characteristics during the TAMU TRACER Field Campaign.” American Meteorological Society 102nd Annual Meeting.

Jensen, MP. 2022. “An overview of TRACER(+) Science and Operations.” DOE Atmospheric Systems Research Principal Investigators/Science Team Meeting. Rockville, Maryland.

Sharma, M, AD Rapp, and CJ Nowotarski. 2022. “Preliminary overview of the TAMU TRACER sounding data set.” TRACER monthly science workshop, Virtual.

3.2 Poster Presentations

Langford, PD, CJ Nowotarski, AD Rapp, C Hood, and M Sharma. 2023. “Analyzing Properties of Outflow Boundaries Relating to Sea Breeze Convection.” American Meteorological Society 22nd Annual Student Conference.

Tomerlin, B, C Hood, M Sharma, CJ Nowotarski, and AD Rapp. 2023. “CSAPR Radar Cell Tracking Performance and Airmass Effect on Storms during TRACER.” American Meteorological Society 22nd Annual Student Conference.

Hood, C, B Tomerlin, CJ Nowotarski, M Sharma, and AD Rapp. 2023. “Cataloging Parent Airmass of Convective Cells during Enhanced Operations of TRACER.” American Meteorological Society 22nd Annual Student Conference.

Rapp, AD, SD Brooks, CJ Nowotarski, E Nielsen, M Sharma, M Etten-Bohm, SA Thompson, B Chen, R Li, and B Hendrickson. 2022. "TAMU TRACER: A First Look." DOE Atmospheric Systems Research Principal Investigators/Science Team Meeting, Rockville, Maryland.

Jensen, MP, et al. (including SD Brooks, CJ Nowotarski, and AD Rapp). 2022. "An Overview of the Tracking Aerosol Convection interactions ExpeRiment (TRACER)." DOE Atmospheric Systems Research Principal Investigators/Science Team Meeting. Rockville, Maryland.

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