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TRACER-Sonde: O_3 as a Tracer of Convective Mixing Field Campaign Report

P Walter
Y Wang
S Yoon
S Usenko
J Flynn
N Partida
R Sheesley

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ARM

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P Walter, St. Edward's University
J Flynn, University of Houston (UH)
Y Wang, UH
N Partida, UH
S Yoon, UH
R Sheesley, Baylor University (BU)
S Usenko, BU

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Acronyms and Abbreviations

AMF	ARM Mobile Facility
ARM	Atmospheric Radiation Measurement
IOP	intensive operational period
LT	local time
MAQL	mobile air quality laboratory
TRACER	Tracking Aerosol Convection Interactions Experiment
UTC	Coordinated Universal Time
VOC	volatile organic compound

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1.0 Summary

The U.S. Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) Tracking Aerosol Convection Interactions ExpeRiment (TRACER) in the greater Houston area from October 2021-September 2022 investigated convective cloud life cycles and aerosol-convection interactions through a comprehensive data collection (Jensen 2019, 2022). TRACER-Sonde (also known as TRACER-O_3), a sub-campaign of TRACER, took place from July to September 2022 during the TRACER intensive operating period (IOP) at the M1 Main ARM site (29.670° N, 95.059° W) at the La Porte airport (Figure 1), which was the location for the first ARM Mobile Facility (AMF1).

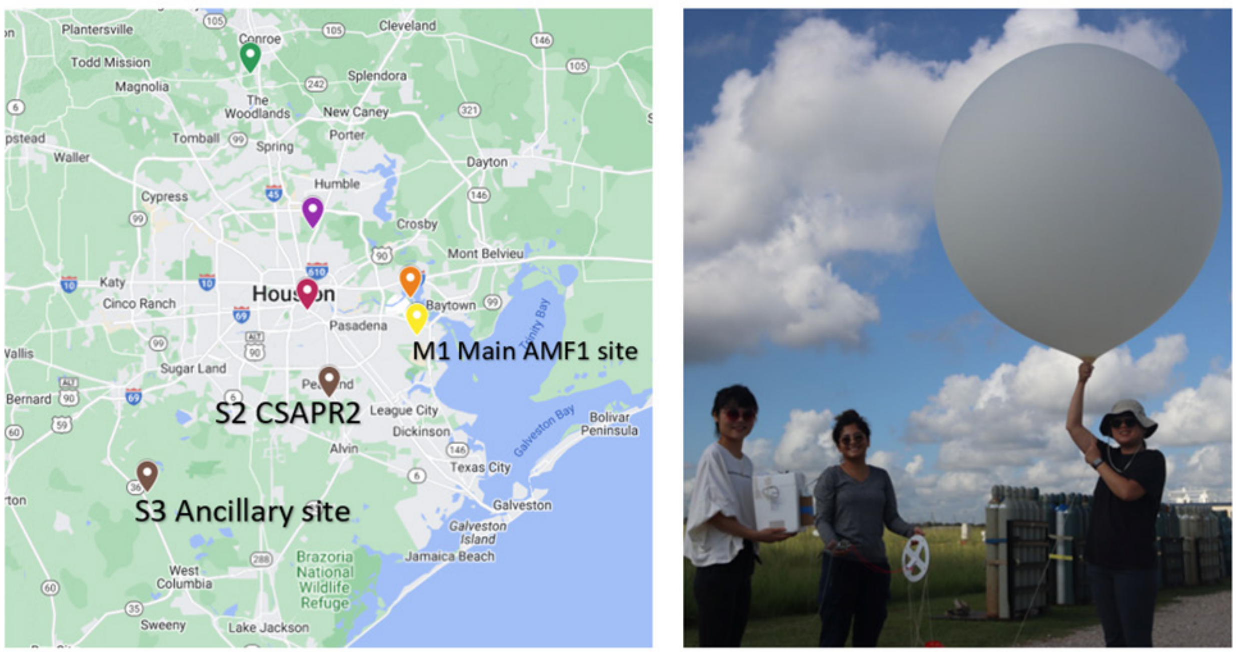

Figure 1. Left: The location of the Main site (M1, yellow), which was the location of the TRACER-Sonde ozonesonde launches, relative to other ARM sites (brown) during TRACER. The different sites used by TRACER-MAP are shown by the colored pins. Right: An ozonesonde connected to a weather balloon just prior to launch.

The TRACER-Sonde campaign used electrochemical cell ozonesondes (Komhyr 1969, 1986) to measure vertical profiles of ozone, which can be a tracer for convective mixing, in conjunction with meteorological variables measured by a radiosonde. The uncertainty in the ozone measurement ranges from 5-10% in the troposphere (Tarasick et al. 2021, Witte et al. 2018). Table 1 lists the 32 days in which TRACER-Sonde had twice-daily ozonesondes from the M1 site at ~11Z[1] and ~15Z (6 am and 10 am LT). The ozonesonde profiles provide an additional method to validate boundary-layer height determinations and test assumptions about vertical mixing in pre-convective environments.

[1] Z is for Zulu time or Coordinated Universal Time (UTC). Local Time (LT) during TRACER-Sonde was UTC-5.

Table 1. Listing of days in 2022 with twice-daily ozonesondes (~11 UTC and ~15 UTC launch times; 6 am and 10 am LT) from the M1 Main site (AMF1 location) at the La Porte airport. Days with a radiosonde at 15 UTC (10 am LT) are shown in blue. Enhanced sounding days with additional radiosondes during the TRACER IOP are shown in yellow (June is not shown). Days where TRACER-MAP was stationed at the M1 Main site are shown in yellow and its other locations are colored coded with the pins in the map on Figure 1. **Days with unsuitable balloon trajectories for ozonesondes. ***Enhanced soundings were called off.

July	1-Jul	2-Jul	3-Jul	4-Jul	5-Jul	6-Jul	7-Jul	8-Jul	9-Jul	10-Jul	11-Jul	12-Jul	13-Jul	14-Jul	15-Jul	16-Jul	17-Jul	18-Jul	19-Jul	20-Jul	21-Jul	22-Jul	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul
Enhanced Soundings																***															
Ozonesondes	**	**			2	2				**	**	2	2	2		2											2	**	2	2	
TRACER-MAP																															

August	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug	26-Aug	27-Aug	28-Aug	29-Aug	30-Aug	31-Aug
Enhanced Soundings																															
Ozonesondes	**	**	**	2	2	2	2	2	2	2										2	2	2				**	2	2			
15Z radiosonde																										1					
TRACER-MAP																															

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
Enhanced Soundings																														
Ozonesondes		**				2			2	2	2	2	2	**	**	**	**	**	2	2	2	**	**	**	**	**	**	**	2	2
15Z radiosonde		1														1	1	1							1					
TRACER-MAP																														

During the TRACER campaign, regular radiosondes were launched from the M1 Main AMF1 site four times daily at 00Z, 06Z, 12Z, and 18Z. During the TRACER IOP, ~10 days per month that were forecast to have isolated convective activity had enhanced soundings with additional radiosondes from the M1 site at 1930Z, 21Z, and 2230Z and the S3 Ancillary site at 18Z, 1930Z, 21Z, 2230Z, and 00Z. Seventeen of the days with TRACER-Sonde ozonesonde launches occurred on enhanced sounding days. While the ozonesonde balloon train includes a parachute, the mass of the payload (~1.5 kg) is such that launches do not occur when forecast trajectories predict the balloon payload to land in a densely populated area. On six TRACER enhanced sounding days where the trajectories were unsuitable for ozonesondes, a radiosonde was launched at 15Z to better characterize the atmosphere prior to the onset of afternoon convection.

TRACER-MAP, another sub-campaign of TRACER[2], deployed a mobile air quality lab 2 (MAQL2) measuring trace gases, aerosol, and volatile organic compounds (VOCs) that was positioned at different locations in the greater Houston area to investigate the impacts of convective storms.

[2] In September 2022, the MAQL2 measurements were funded by the Texas Commission on Environmental Quality.

2.0 Results

When paired with in situ gas, aerosol, and boundary-layer height measurements from instruments located at AMF1 and the TRACER-MAP campaign, the ozonesonde data can provide insight into the representativeness of the ground level data relative to conditions aloft. In addition to providing information on the oxidative capacity of the environment, ozone can also be used as a chemical tracer of boundary-layer dynamics and convective mixing. Ozonesonde profiles from pre-dawn (11Z) flights often show strong gradients in the stable nocturnal boundary layer as well as within the residual layer aloft, while late-morning (15Z) launches tend to show a more well mixed convective boundary layer. Analyzed together, these profiles can help understand both the growth of the boundary layer through morning convective mixing and also the downward mixing of lofted species, which can impact aerosol processing.

Two examples of the twice-daily ozonesonde profiles from the M1 site for 12 July and 9 August 2022 are shown in Figure 2. Both were days with enhanced TRACER soundings. There is a large gradient in the pre-dawn (11Z) ozone profiles (light blue) near the surface. On 9 August, the variability of the 15Z potential temperature profile (dark red) between 1-2 km is an indication that convection was underway over La Porte in the late morning.

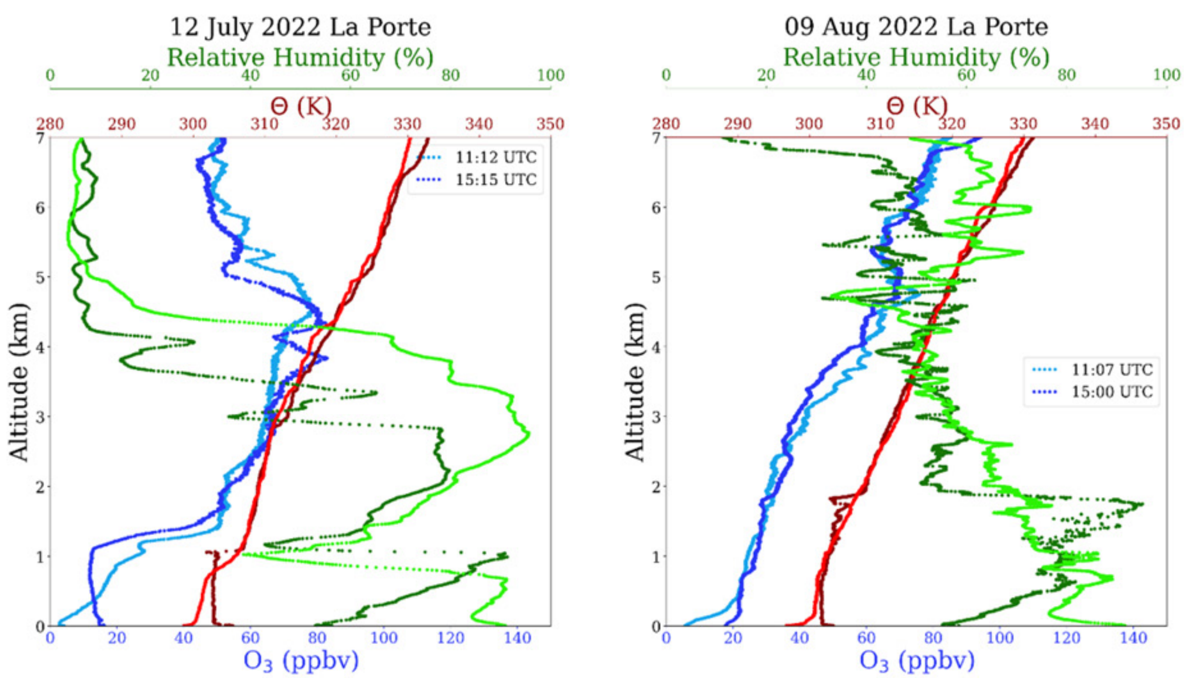

Figure 2. Ozonesonde profiles from 12 July and 9 August 2022 showing ozone (blue), relative humidity (green), and potential temperature (red) for the first 7 km. The lighter colors are for the 11Z sounding and the darker colors are for the 15Z sounding.

Profiles of ozone, along with meteorological parameters from the radiosonde, can be used to identify effects of vertical mixing of free-tropospheric and boundary-layer air masses. Ozone and equivalent potential temperature are conserved during adiabatic convective mixing and can serve as tracers for determining the origin height of downdrafts (Betts et al. 2002). In general, the ozonesonde profiles can be used in conjunction with ARM measurements (e.g., Doppler lidar, radio wind profilers) to describe vertical motions in the atmosphere. Equivalent potential temperature profiles from radiosonde measurements can place constraints on entrainment (Eissner et al. 2021, Jensen and Del Genio 2006), which can be further constrained by the TRACER-Sonde ozone profiles. Profiles of ozone and meteorological variables can be also used for modeling validation of convective events and air quality episodes.

3.0 Publications and References

3.1 Presentations

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4.0 Lessons Learned

At the M1 Main AMF1 site, regular radiosondes were released four times daily at 00Z, 06Z, 12Z, and 18Z. On enhanced sounding days additional soundings took place at 1930Z, 21Z, and 2230Z at the M1 site and at 18Z, 1930Z, 21Z, 2230Z, and 00Z at the S3 Ancillary site. We received comments a few times that the 15Z soundings from the M1 site were helpful to forecasters. In particular, they were interested in the SkewT plots obtained from the radiosonde data. In a future campaign with enhanced afternoon soundings, it may be worthwhile to modestly increase the frequency of morning soundings.

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