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# EPCAPE-Partitioning Thrust-Los Alamos National Laboratory (EPCAPE-PT-LANL) Field Campaign Report

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ARM

## DISCLAIMER

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# Acronyms and Abbreviations

| | |
|---|---|
| AOS | Aerosol Observing System |
| APS | aerodynamic particle sizer |
| ARM | Atmospheric Radiation Measurement |
| BC | black carbon |
| CCNC | cloud condensation nuclei counter |
| CHARON | chemical analysis of aerosol online |
| CPC | condensation particle counter |
| EPCAPE | Eastern Pacific Cloud Aerosol Precipitation Experiment |
| EPCAPE-PT | EPCAPE-Partitioning Thrust |
| GCVI | ground-based counterflow virtual impactor |
| H-CAPS-PMSSA | humidified cavity-attenuated phase shift particulate matter single-scattering albedometer |
| IOP | intensive operational period |
| LANL | Los Alamos National Laboratory |
| Nanoscan | NanoScan SMPS Nanoparticle Sizer 3910 |
| PAX | photoacoustic extinctiometer |
| PTRMS | proton transfer reaction – mass spectrometry |
| PTR-TOF | proton-transfer reaction time-of-flight mass spectrometer |
| rBC | refractory black carbon |
| SMPS | scanning mobility particle sizer |
| SP2 | single-particle soot photometer |
| SP-AMS | soot-particle aerosol mass spectrometer |
| UTC | Coordinated Universal Time |
| VOC | volatile organic compound |
| WIBS | wideband aerosol bioaerosol sensor |

# Contents



# Figures



# Tables

# 1.0 Summary

Coastal cities offer a unique environment for studying aerosol-cloud interactions and the effects of urban emissions on aerosol and cloud properties. As part of the U.S. Department of Energy Atmospheric Radiation Measurement (ARM)'s Eastern Pacific Cloud Aerosol Precipitation Experiment (EPCAPE), the Partitioning Thrust by Los Alamos National Laboratory (EPCAPE-PT-LANL) was conducted to complement the science goals of EPCAPE and add additional in-depth measurements of aerosols and clouds at Mt. Soledad. Our campaign focused on measuring the physical, optical, and chemical properties of aerosols, trace gases, and their interactions within marine stratocumulus clouds in La Jolla, California (see Figure 1). Three primary science goals motivated the EPCAPE-PT-LANL campaign:

- How is the chemical composition of cloud droplet residuals distinct from un-activated aerosol and how does cloud-processing change increase/decrease cloud supersaturation?
- What is the role of gas-phase compounds in enhancing water solubility and lowering supersaturation required for cloud droplet activation in clean and polluted conditions at Mt. Soledad?
- How will residual aerosol particles left over after a cloud dissipates alter future cloud-formation? Does cloud-processing affect generation of hydroxl radical (OH-) by aerosol in cloud "bursts"?

EPCAPE-PT-LANL enhanced the primary goals of EPCAPE through observations between aerosols and cloud droplets, the impact of black carbon (BC) on aerosol-cloud interactions, and the effects of cloud processing on aerosol optical properties.


**Figure 1**. Left: main inlet and ground-based counterflow virtual impactor (GCVI) with picture taken during cloud sampling. Right: picture of the EPCAPE-PT-LANL instrument container at the Cloud Instrument Site on Mt. Soledad site with a view towards the Pacific Ocean showing the EPCAPE main site for the ARM Mobile Facility on the Scripps Pier [1].

A key instrument during our intensive operational period (IOP) was a ground-based counterflow virtual impactor (GCVI), which selected cloud droplets from interstitial particles, allowing detailed analysis of components within the cloud droplets. We aimed to assess how gas-phase organics were incorporated into

cloud droplets, dependent on the solubility and oxidation conditions of the organic vapors. To achieve this, we used LANL's new proton-transfer reaction time-of-flight mass spectrometer (PTR-TOF, Ionicon Analytik Ges.m.b.H.) with a chemical analysis of aerosol online (CHARON) particle inlet. This was in addition to measurements from a soot-particle aerosol mass spectrometer (SP-AMS, Aerodyne Research Inc.) and a single-particle soot photometer (SP2, Droplet Measurement Technologies). We also measured the water uptake of particles at relative humidity levels both below and above 100% using our humidified cavity-attenuated phase-shift particulate matter single-scattering albedometer (H-CAPS-PMSSA, Aerodyne Research Inc.) and a cloud condensation nuclei counter (CCNC, Droplet Measurement Technologies). This comprehensive study of aerosol processing is crucial for advancing our understanding of aerosol-cloud interactions.

## 1.1 Intensive Operational Period Deployment

The IOP spanned Friday, October 20, 2023, to Monday, December 4, 2023, conducted on Mt. Soledad at the EPCAPE supplementary site located at latitude 32.8404 and longitude -117.2498. The core instrument setup was categorized into three groups based on their connection to the main inlet, the switchable GCVI and the main inlet (see Figure 1), and a separate category for external instruments.

- Main Inlet: Gas-phase instruments connected solely to the main inlet included Picarro analyzers for CO, $CO_2$, $CH_4$, $H_2O$, 2B-Technologies for NOx measurements, and the PTR-TOF for gas-phase analysis.
- GCVI and Main Inlet: This setup included the PTR-TOF CHARON particle-phase measurements, SP-AMS, SP2, a scanning mobility particle sizer (replaced by TSI NanoScan on November 22, 2023), an aerodynamic particle sizer (APS, Aerodyne Research Inc.), a photoacoustic extinctiometer at 870 nm (Droplet Measurement Technology), a humidified cavity-attenuated phase-shift PMSSA (Aerodyne Research Inc.), a single-column CCNC (Droplet Measurement Technology), a condensation particle counter (CPC, TSI), and the wideband integrated bioaerosol sensor (WIBS, Droplet Measurement Technology).
- External (no inlet): Devices operating externally included the Quant-AQ MODULAIR™ and the GCVI weather station.

Particle measurements were conducted via a 1-micron (8 LPM) cyclone and were dried using Nafion driers. The campaign included 68 cloud sampling periods, totaling 86 minutes of cloud sample time.

## 1.2 Data Processing and Availability

Data from 15 instruments deployed during IOP have been submitted and should be available this month via open access on ARM Data Discovery and cited via https://doi.org/10.5439/2369584. Table 1 shows a summary of the posted data. The data has been merged into 10-second (when available) and 10-minute-averaged data reported in UTC.

**Table 1**. Categorized list of instruments, measurements, and data available in ARM Data Discovery.

| *Category* | Instrument Name | Data | 10 sec | 10 min |
|---|---|---|---|---|
| *Aerosol* | APS | supermicron size distributions | | x |
| | H-CAPS | Humidified aerosol extinction and scattering | x | x |
| | CCN | cloud condensation nuclei concentration | x | x |
| | CPC | submicron particle concentration | x | x |
| | GCVI | meteorological conditions | x | x |
| | PAX | aerosol absorption and extinction | x | x |
| | Nanoscan | submicron size distributions | | x |
| | SMPS | submicron size distributions | | x |
| | SP-AMS | aerosol chemical composition | | x |
| | SP2 | black carbon concentration | x | x |
| | WIBS | primary biological particles | | x |
| *Gas-phase* | NOx | NOx | x | x |
| | Picarro | $CO/CH_4/CO_2/H_2O$ | x | x |
| | PTRMS | Volatile organic compounds | | x |
| *External* | Modulair | PM and trace gases | x | x |

# 2.0 Results

## 2.1 Black Carbon Analysis

Typical mass concentrations of rBC at the Mt. Soledad site were 170 ng•m$^{-3}$ (Figure 2). A maximum value of 7,400 ng•m$^{-3}$ was observed on 31 Oct 2024. The SP2 measured ambient air for 88% of the sampling period. 10% of the sampling period was flagged, primarily due to deviations in sample flow rate, resulting in higher uncertainties in the data quality (Figure 2). The sample flow rate can affect the duration of a particle passing through the laser and thus the incandescence from the particle that is used to determine its rBC mass. It can also affect how focused the aerosol flow through the laser cavity was by creating an imbalance with the sheath flow. Additional flagged periods (~2% of the data) occurred during brief periods when the primary threshold for particle detection was erroneously high or when the laser power dipped.

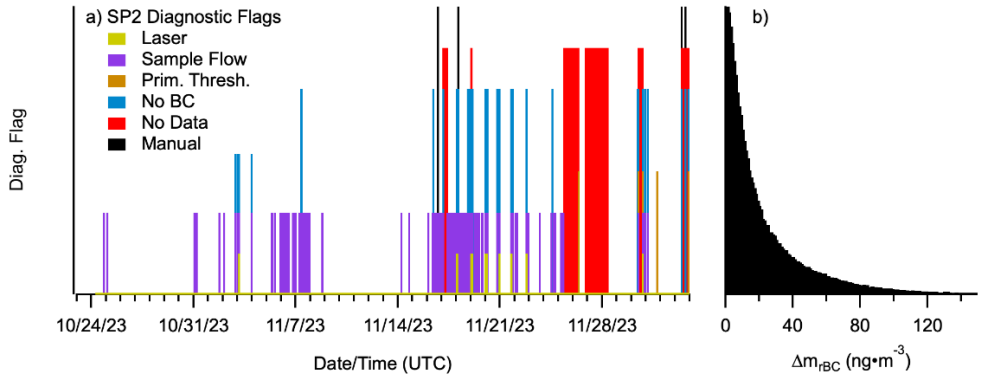


**Figure 2**. Left: diagnostic flags for the SP2 data. Right: difference in mass concentration between sequential 10-second windows.

The flagged data are included in Figure 2 and show the general stability of the measurements despite deviations in the sample flow rate. This was exemplified between 16 and 20 November 2023 with good agreement between the flagged and unflagged data. During this period, the ultra-zero air generator that supplied clean air for the sheath flow and purge flow failed and the sample flow rate was ~480 $cm^3 \cdot min^{-1}$ (set point of 120 $cm^3 \cdot m^{-1}$). In addition to the change in flow rate and sheath-to-flow ratio, the sample flow during this period was susceptible to upstream pressure changes caused by co-located instrumentation.

rBC number concentrations were compared to total submicron number concentrations measured by the CPC (Figure 3). Variations in BC concentration tended to correspond with variations in total submicron number concentration. An inset in Figure 3 shows a 2.5-hour period that exemplifies the covariance of rBC with total submicron number concentration. Additionally, the BC mass concentration showed reasonable agreement within measurement uncertainties when compared with the BC that was measured by the SP-AMS (not shown) between 27 November and 3 December, when the SP-AMS laser vaporizer was operating.

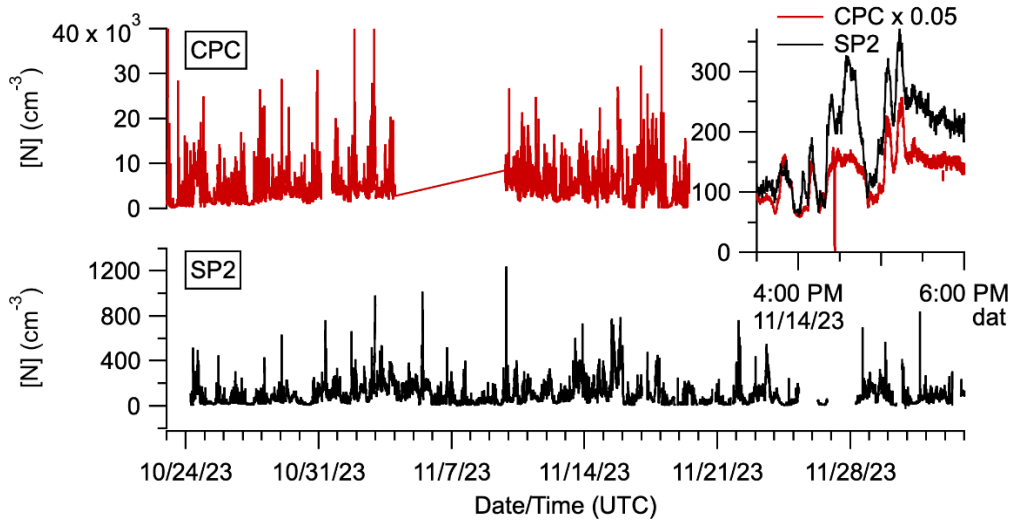


**Figure 3**. Comparison of total submicron number concentration measured by the CPC with the rBC number concentration.

## 2.2 Aerosol Chemical Analysis

The measurement period generally exhibited low submicron non-refractory aerosol concentrations, typically below 5 $\mu g \cdot m^{-3}$, with instances of elevated organic, sulfate, and nitrate aerosol lasting from several hours to days (Figure 2). Notably, a significant local aerosol event occurred approximately 77.5 km away—the Highland fire, which burned 2,487 acres from October 30 to November 7, 2023, at coordinates 33.4382, -116.8231 [2]. This incident likely contributed to the increased organic aerosol concentrations observed during this period. Figure 4 also provides meteorological context with bars marking in-cloud (GCVI) sampling periods.

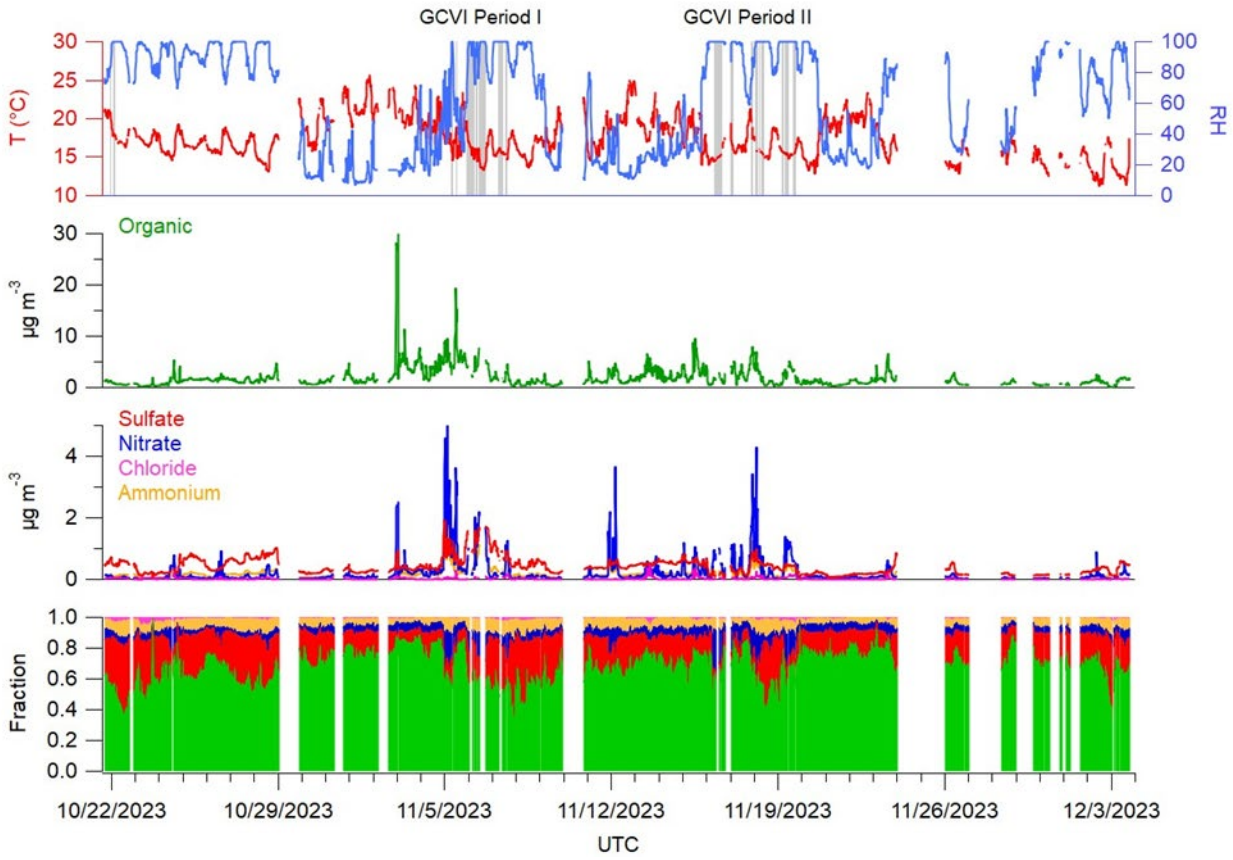


**Figure 4**. The times series of non-refractory aerosol composition from the SP-AMS with meteorology and GCVI inlet measurement periods in gray.

The initial results from the aerosol measurements on the GCVI inlet illustrated differences in chemical composition between the cloud residuals and out-of-cloud aerosols observed during the periods just prior and after the cloud event as shown during the two distinct periods in Figure 5. For example, on November 16, when comparing the cloud droplet residuals (GCVI inlet) and out-of-cloud states (main inlet), we observed an increase in the mass fraction of nitrate ($NO_3$), and ammonium ($NH_4$) during the in-cloud periods. This suggests effective scavenging and processing of these aerosols within the cloud environment. In contrast, on November 17-18, the mass fractions were nearly identical for the cloud-residuals and out-of-cloud measurements. However, the mass concentrations are significantly different (see Figure 5 far right). These contrasting results emphasized the dynamic interactions between aerosols and cloud processes and highlight the utility of the GCVI inlet for capturing these variations effectively for real-time in situ aerosol measurements.

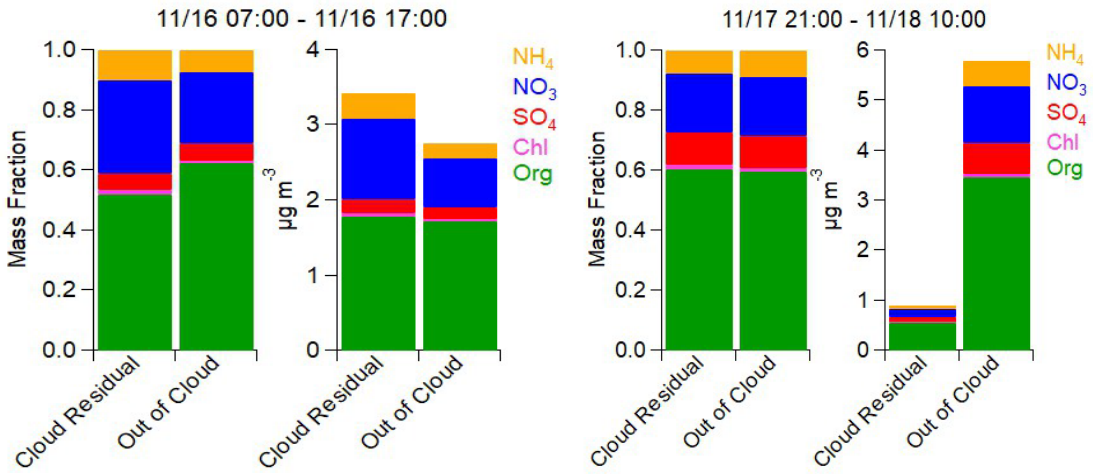


**Figure 5**. Aerosol non-refractory chemical composition from the SP-AMS using the GCVI inlet sampled during two periods, demonstrating in-cloud (GCVI On) versus out-of-cloud (GCVI Off, main inlet) scenarios. Key aerosol components measured, including $NH_4$ (ammonium), $NO_3$ (nitrate), $SO_4$ (sulfate), Chl (chloride), and Org (organics), are presented in terms of mass fraction (left bars of each pair) and concentration in μg/m³ (right bars of each pair).

## 2.3 Future Work

Further analysis will focus on the distinctions between cloud droplet residuals and out-of-cloud measurements with our full suite of instruments that include chemical, physical, optical, and hygroscopic properties of aerosol as well as trace gases and VOCs. Specifically, we aim to explore differences in chemical species, optical properties, and hygroscopicity between the cloud droplet residuals and ambient particle measurements made just prior to and after the main cloud events as shown above in Figure 5 from the preliminary non-refractory species from the SP-AMS data. This detailed examination will enhance our understanding of cloud-aerosol interactions with a focus on cloud processing of aerosols and their broader atmospheric impacts as they relate to aerosol lifetimes and direct (radiative) and indirect (cloud properties) climate impacts. Additionally, we plan to integrate our measurements more comprehensively with the longer term EPCAPE observations made by the ARM Aerosol Observing System (AOS) at the pier and other guest instruments that were deployed at Mt. Soledad. This integration will facilitate a more holistic understanding of regional aerosol and cloud dynamics throughout different seasons and cloud regimes. Our coordinated approach will enable us to uncover patterns and trends that are visible when individual data points are considered within the larger scale.

# 3.0 Publications and References

## 3.1 Presentations

Shawon, ASM, KB Benedict, K Gorkowski, RN Farly, NA Franco, JE Lee, MK Dubey, and AC Aiken. 2024. “Clouds and Meteorological Effects on Bioaerosol Particles: Insights From the Eastern Pacific Cloud Aerosol Precipitation Experiment (EPCAPE).” Presented at the American Association for Aerosol Research Annual Conference. Albuquerque, New Mexico.

Farley, R, K Gorkowski, JE Lee, KB Benedict, ASM Shawon, NA Franco, V Berta, LM Russell, MK Dubey, and AC Aiken.. “Influence of Urban and Marine Aerosol on Coastal Cloud Processing at Mt. Soledad in Southern California during EPCAPE.” Presented at the American Association for Aerosol Research Annual Conference. Albuquerque, New Mexico.

## 3.2 References

[1] Image courtesy of the U.S. Department of Energy Atmospheric Radiation Measurement (ARM) user facility. (2023, February 27). EPCAPE https://www.flickr.com/photos/armgov/albums/72177720305315867/

[2] Cal Fire. (2023, December 5). Highland Fire. https://www.fire.ca.gov/incidents/2023/10/30/highland-fire

## 3.3 Planned Submissions

Farley, RN, et al. 2024. “Influence of Urban and Marine Aerosol on Coastal Cloud Processing at Mt. Soledad in Southern California during EPCAPE.” In preparation.

Gorkowski, K, et al. 2025. “Hygroscopic properties and composition of cloud residuals.” In preparation.

## 3.4 Collaborations

- Chemical composition intercomparison – Lynn Russell, University of California–San Diego
- Cloud droplets – Rachel Chang, Dalhousie University
- Metals – Hanyang Li, San Diego State University
- Water Isotopes – Joseph Galewsky, University of New Mexico

# 4.0 Lessons Learned

If the electrical voltage at the container’s outlets is either too high or too low, it is essential to verify that the transformer connected to the container is correctly configured for the onsite voltage. In our case, the container's transformer was incorrectly set for 240 V instead of 208 V, causing the outlets to be in a consistent *brown out* state. While battery backup power supplies helped mitigate this issue, it still took a week to diagnose and correct the transformer’s configuration.


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