



Supplement of

Synthesis of the tethered balloon system and other TRACER campaign measurements elucidates aerosol property profiles

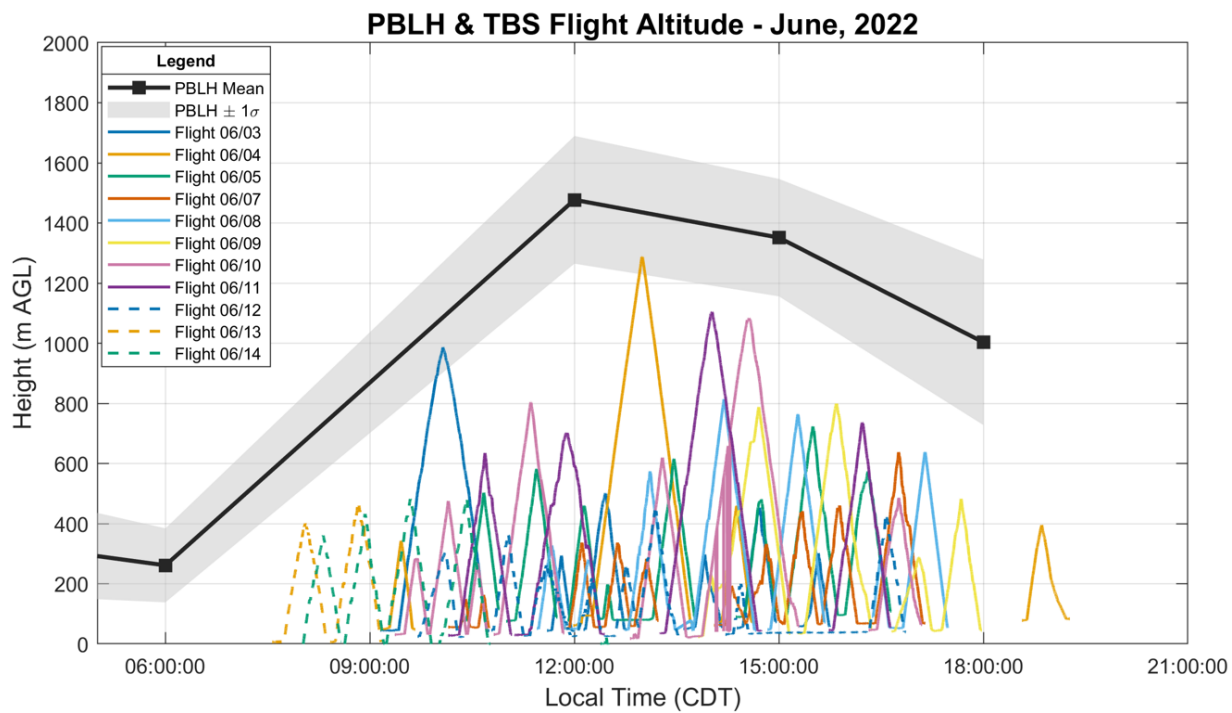
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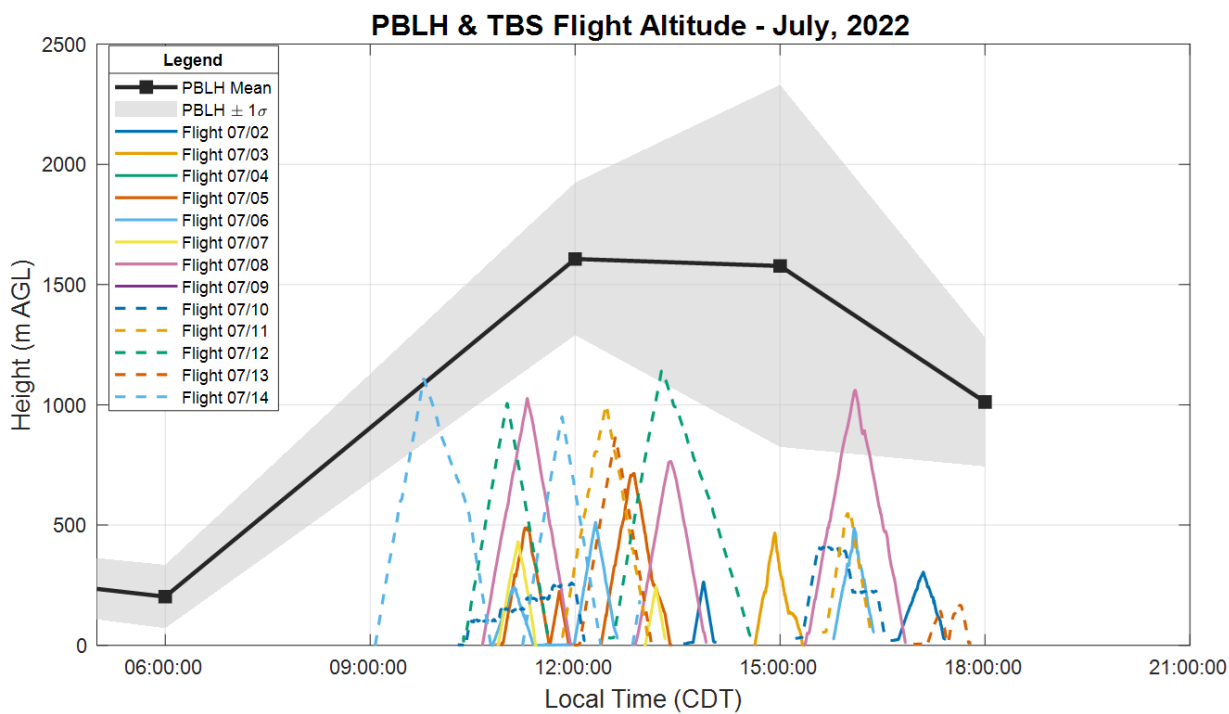
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Figure S1. TBS payload picture during a flight on September 4, 2022



(a)



(b)

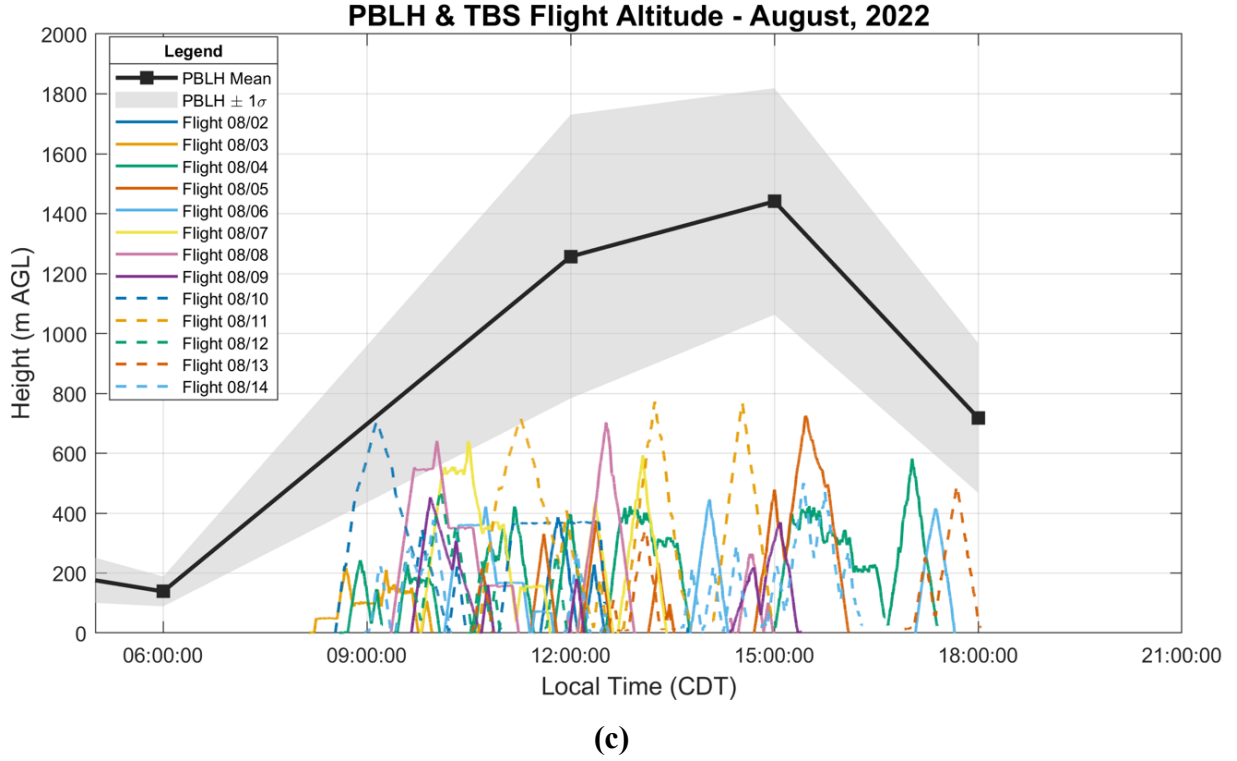


Figure S2. Daily TBS flight altitudes during (a) June (3-14), (b) July (2-14), and (c) August (2-14) 2022, overlaid with the mean monthly PBL height (solid blue line) and its variability (shaded region) derived from radiosonde profiles. Note that the monthly PBL statistics are computed using only days with TBS flights.

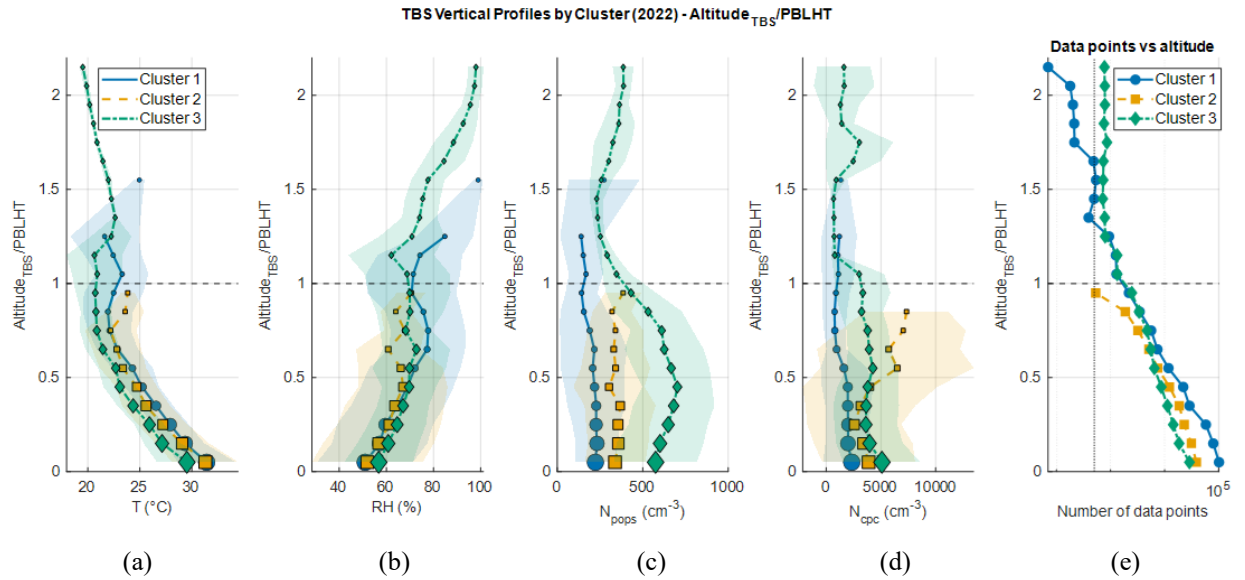


Figure S3. Normalized vertical profiles of atmospheric conditions (a) ambient temperature; (b) ambient relative humidity; (c) total particle concentration measured by the portable optical particle spectrometer (POPS, particles ranging from 135 to 3,000 nm); and (d) total particle concentration measured by the condensation particle counter (CPC, particles greater than 10 nm) (e) data points collected at the corresponding altitude for each cluster with a dash line marks the 500 data points. The square symbols represent the averaged mean values of the sampling periods, while

the error bars denote the standard deviation of the measurements. The altitude was normalized by the boundary layer height derived from radiosonde profiles.

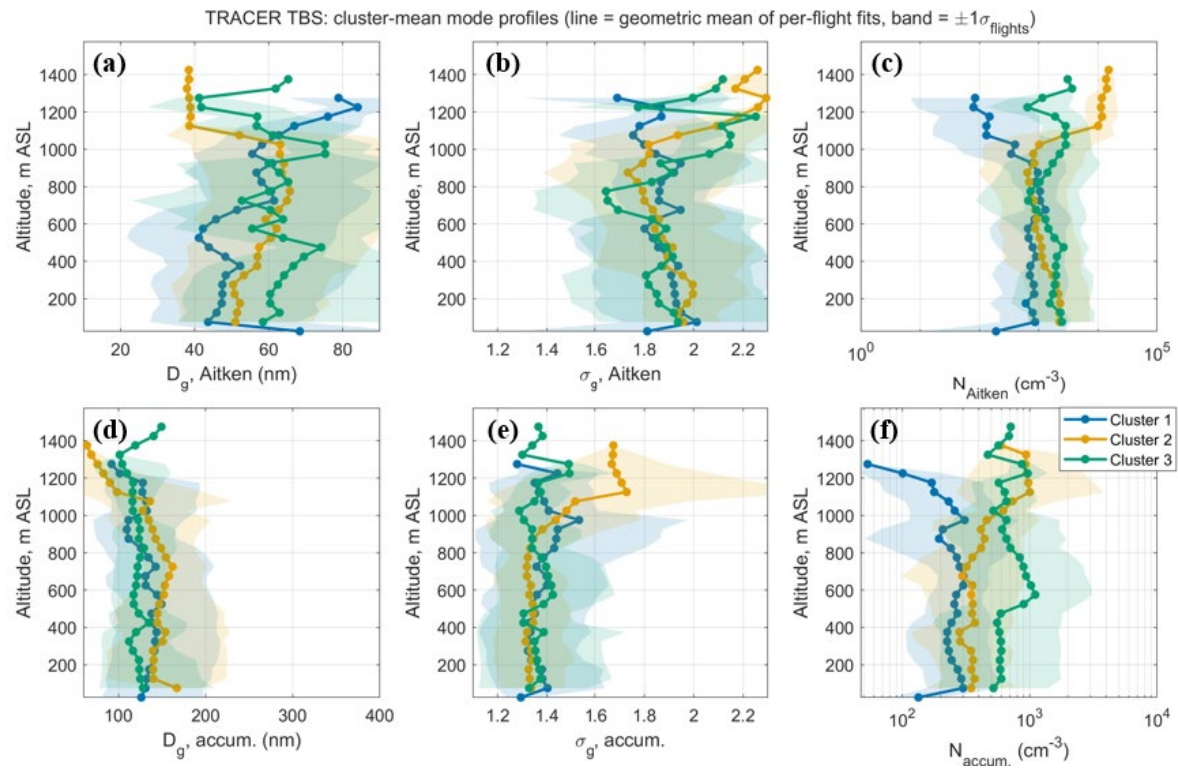


Figure S4, Clustered vertical profiles of aerosol mode parameters from 49 TRACER tethered-balloon flights: geometric mean diameter D_g (a, d), geometric standard deviation σ_g (b, e) and number concentration N (c, f) for the Aitken (top) and accumulation (bottom) modes. Two log-normal modes were fitted to 50-m altitude-binned merged CPC-POPS size distributions for each flight, interpolated onto a common grid and averaged logarithmically within each cluster. Lines denote the geometric mean of per-flight fits; shaded bands denote ± 1 geometric standard deviation across flights. Aitken-mode D_g and σ_g depend on the assumed sub-135 nm reconstruction.

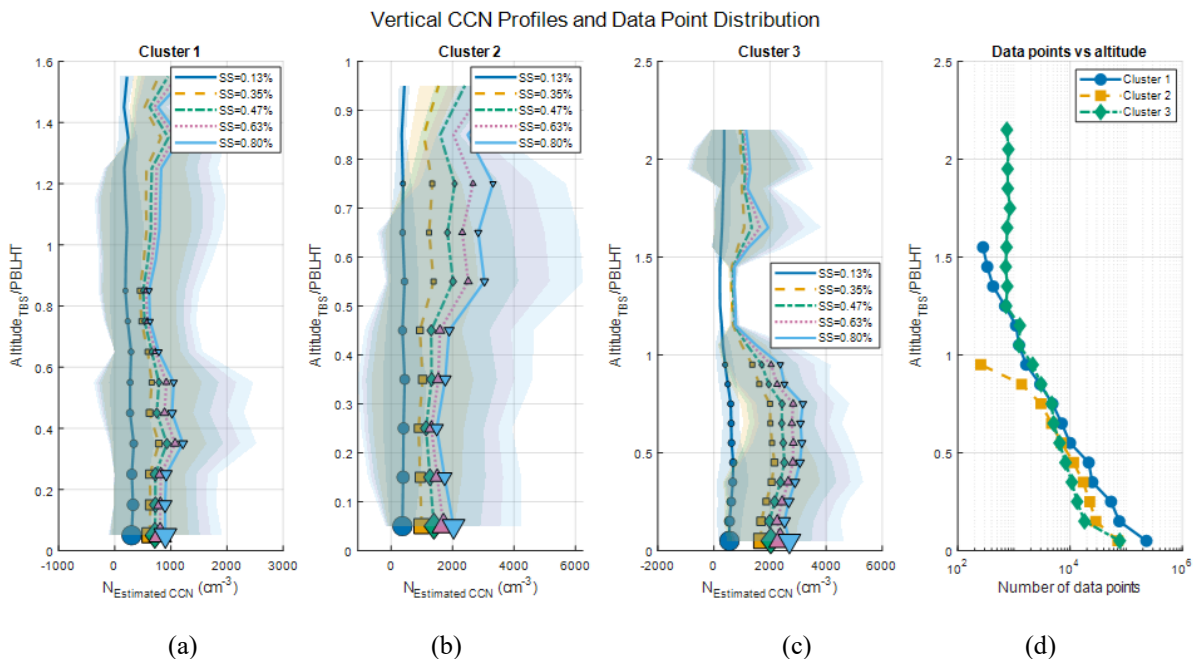


Figure S5. Normalized vertical profiles of estimated CCN concentration against TBS altitude, relative to PBL height, for each cluster (a - c), with data points collected at the corresponding altitude for three clusters (d). **The altitude was normalized by the boundary layer height derived from radiosonde profiles.**

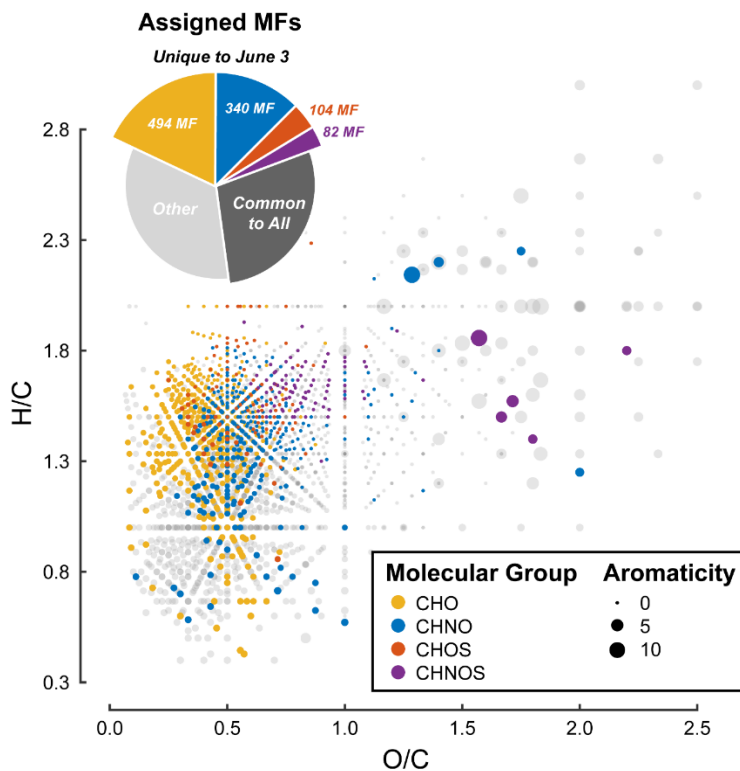
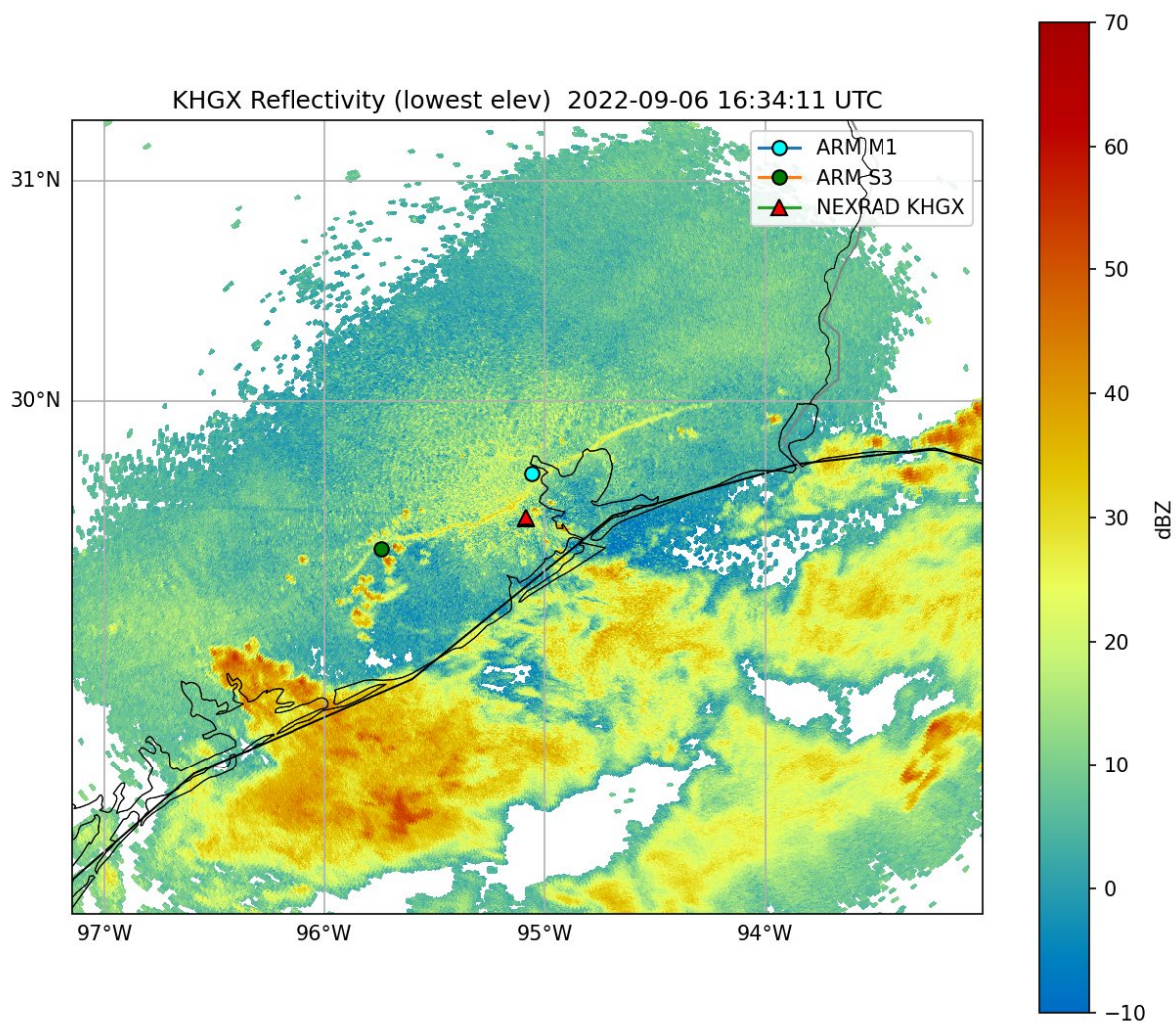
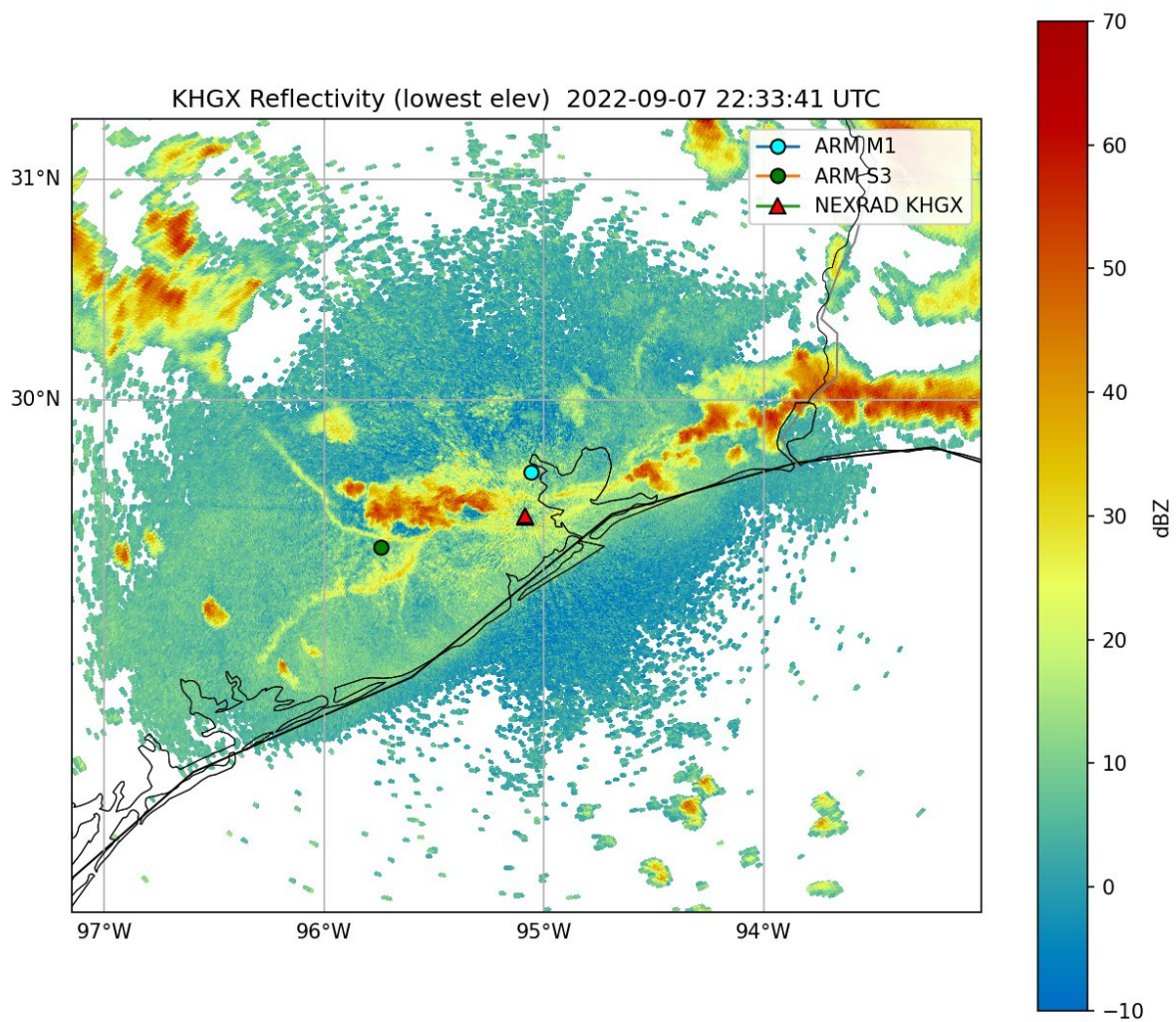


Figure S6. Organic molecular composition of daily ground-level atmospheric particle samples collected from the ANC site during TRACER (June 3). Molecular formulas (MFs) uniquely detected on June 3 (1020 MFs) are color-coded by molecular group for clarity. All MFs are scaled according to the modified aromaticity index.



(a)



(b)

Figure S7, NEXRAD images near the TBS flight periods on (a) September 6, 2022 and (b) September 7, 2022.

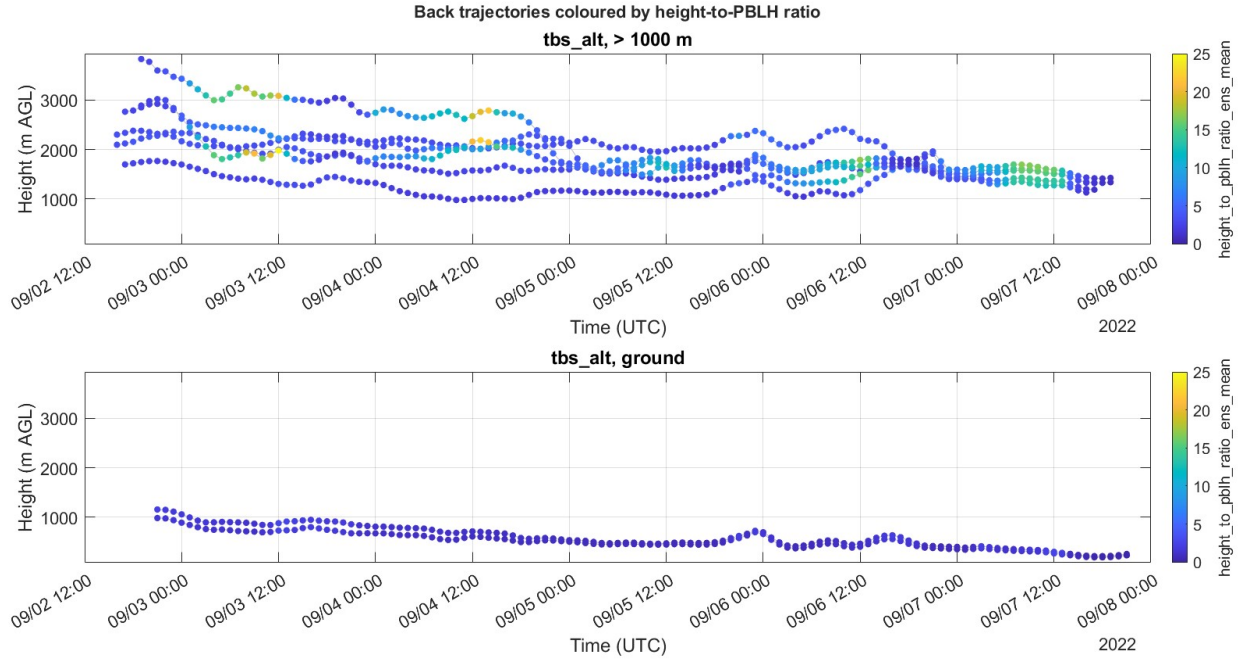


Figure S8. The time series plot shows the temporal evolution of air-mass parameters along trajectories initialized at the center coordinates together with the ensemble mean of the height-to-pblh ratio for September 6 flights.

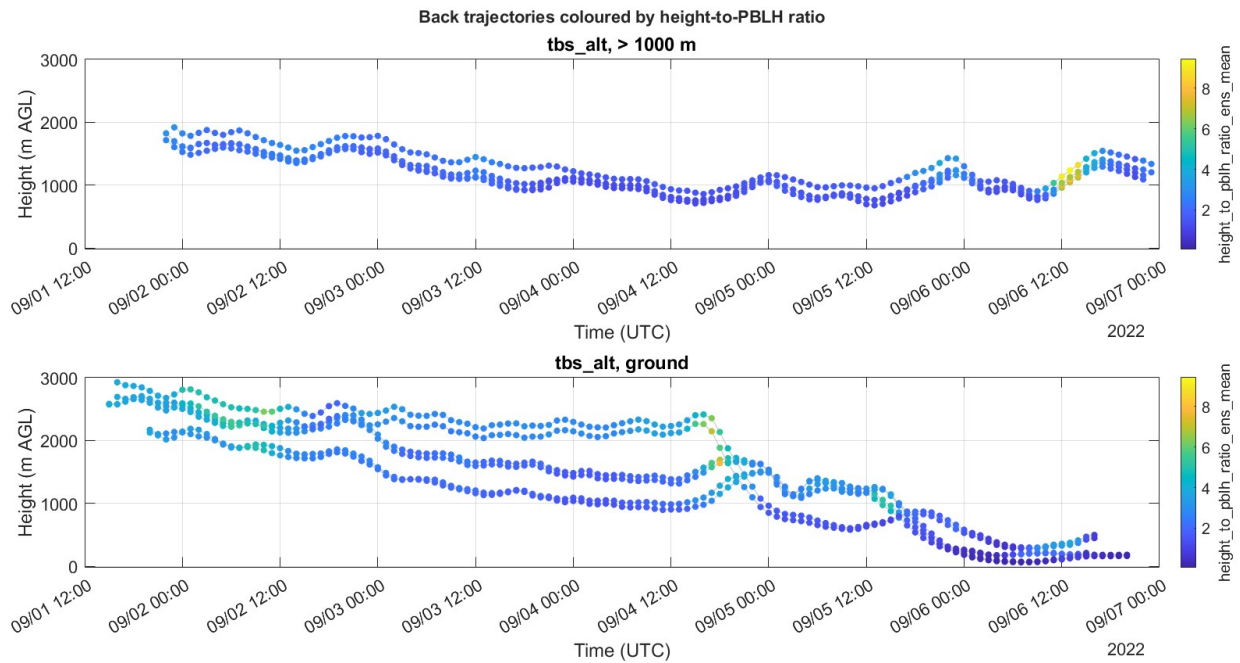


Figure S9. The time series plot shows the temporal evolution of air-mass parameters along trajectories initialized at the center coordinates together with the ensemble mean of the height-to-pblh ratio for September 7 flights.

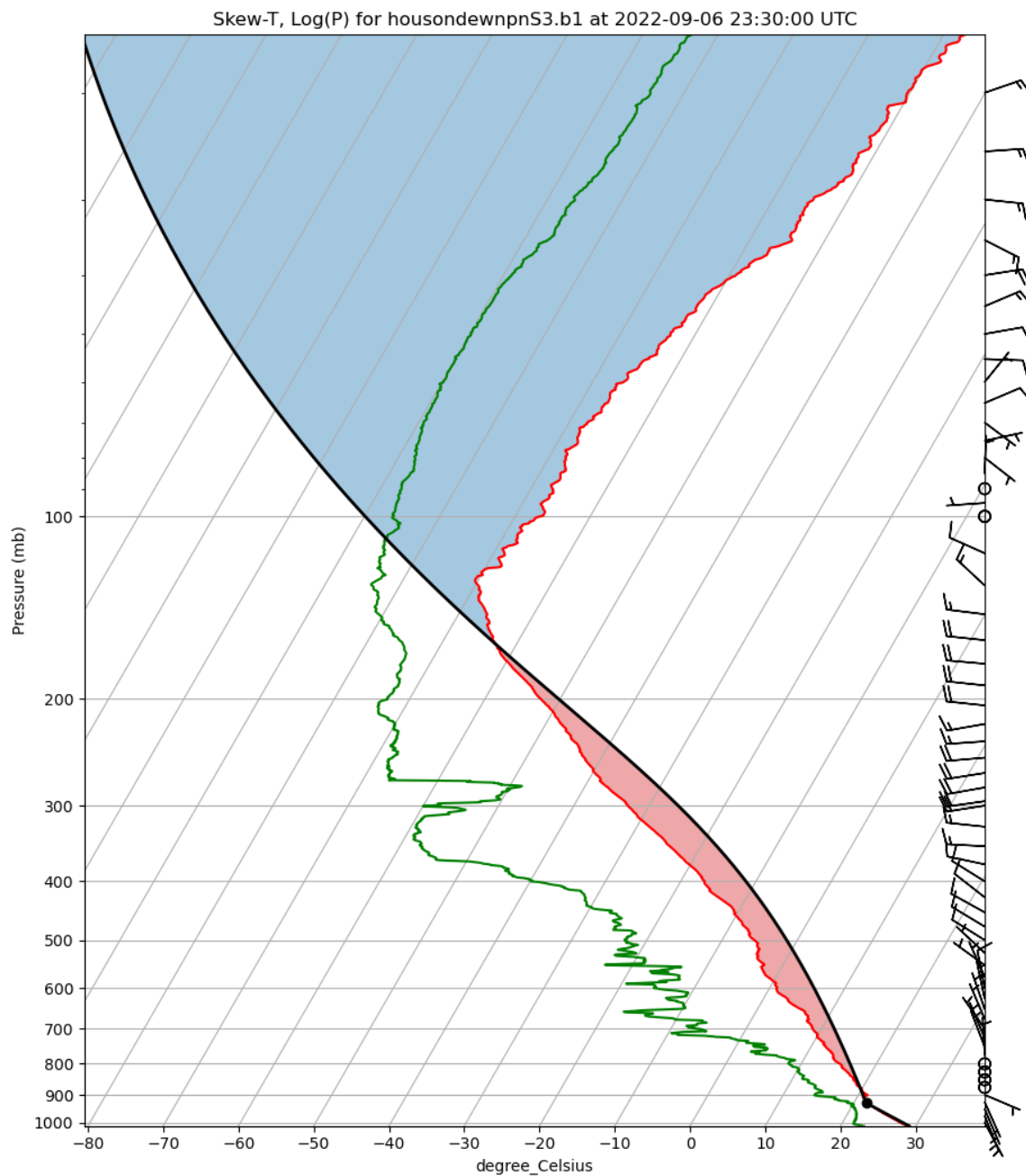


Image provided by ARM Data Quality Office 2022-09-07 01:58:10

Figure S10. Skew-T plot from the radiosonde launched at 23:30 UTC from the ANC site on September 6th, 2022.

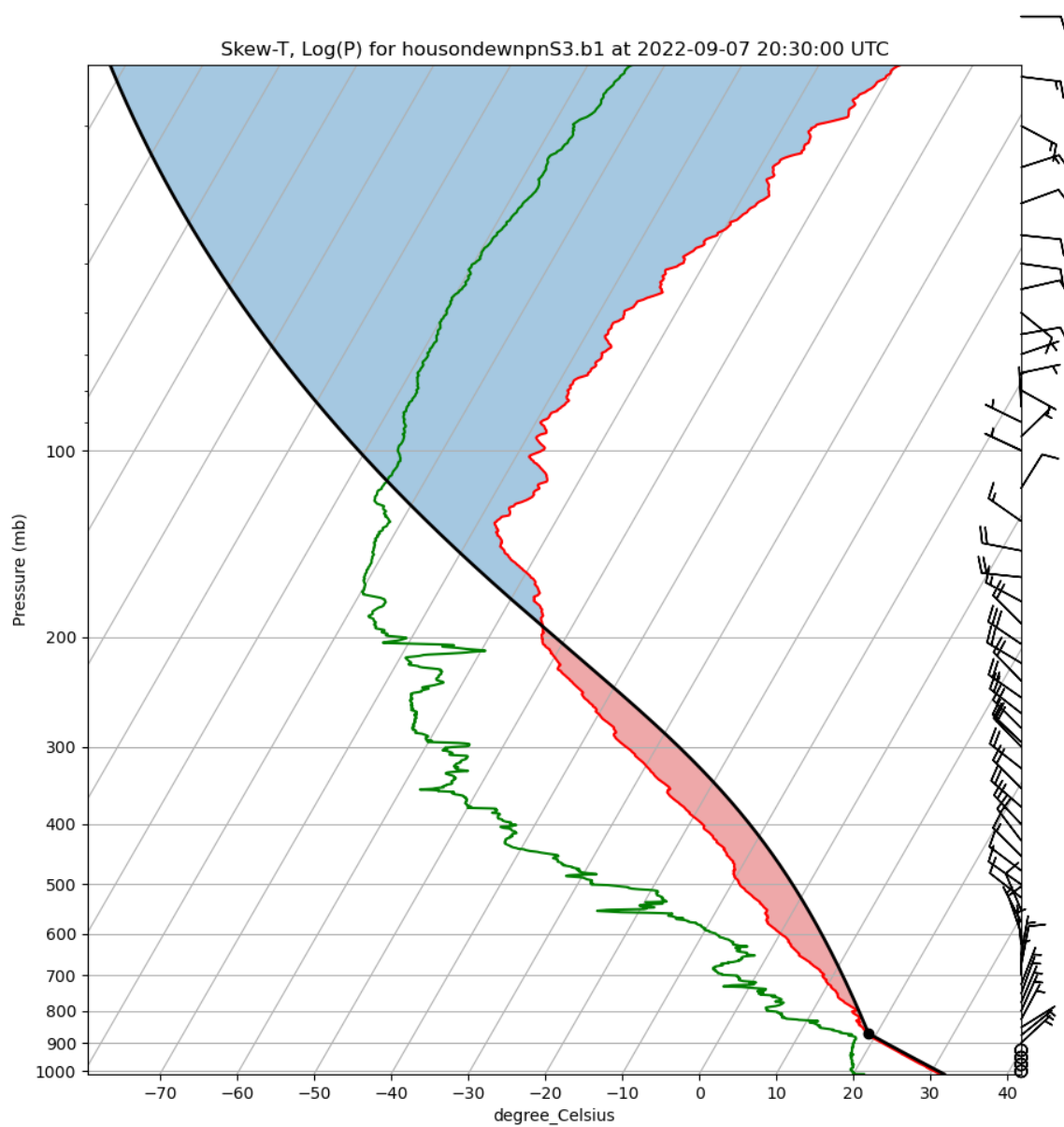


Image provided by ARM Data Quality Office 2022-09-16 19:46:29

Figure S11. Skew-T plot from the radiosonde launched at 20:30 UTC from the ANC site on September 7th, 2022.

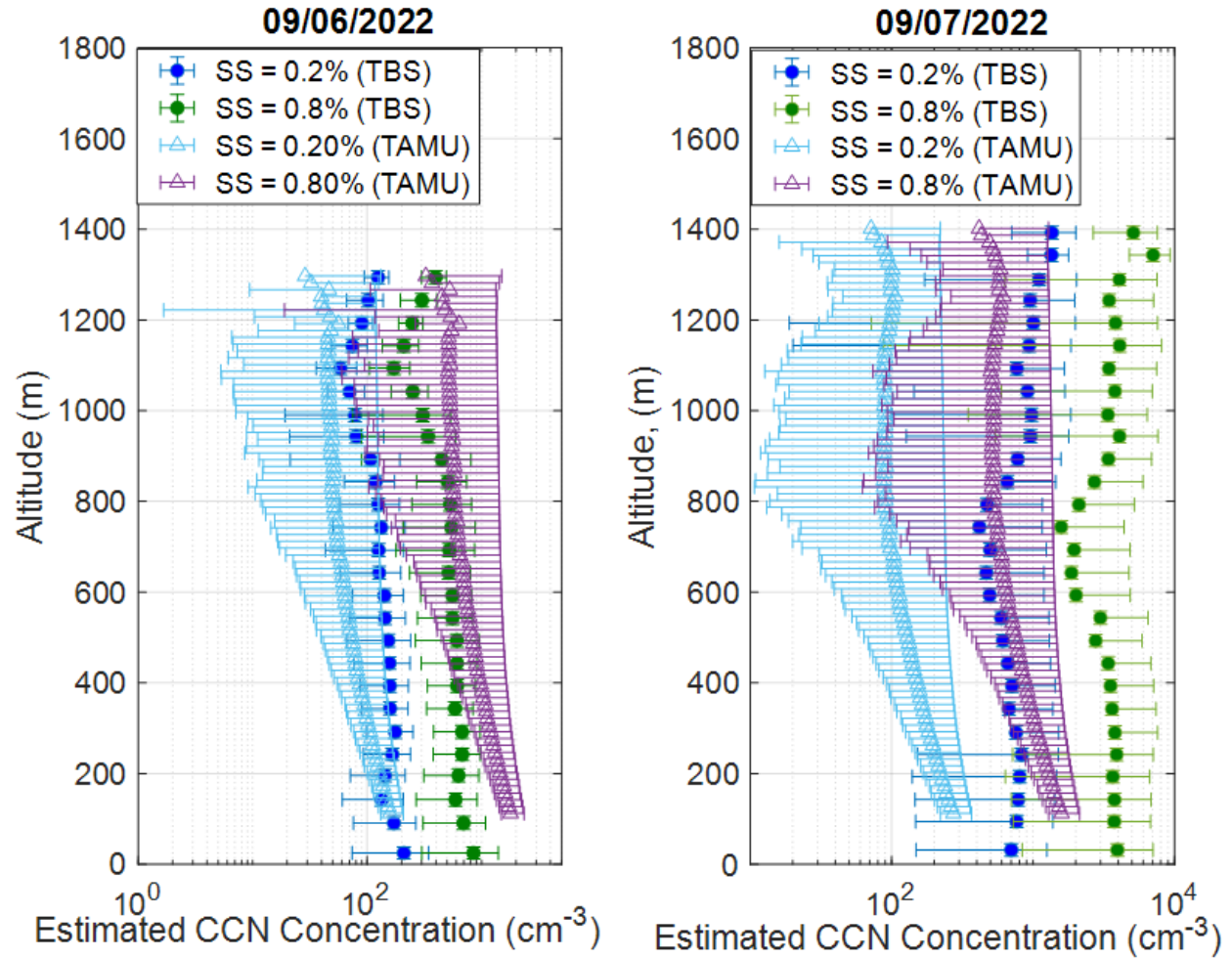


Figure S12. Figure S6. The estimated CCN concentrations using the TBS measurements compared with the MPL retrieved CCN profiles at the supersaturations of 0.2% and 0.8% (a) from September 6, 2022; (b) from September 7, 2022. The triangle and do symbols indicate the mean CCN number concentration; error bars show the standard deviation of CCN concentration during each sampling period.

Table S1. Taking off and landing times of 149 TBS flights

Flights	Time period
1	06/03/2022, 14:10:00, 15:44:00
2	06/03/2022, 16:37:00, 17:00:00
3	06/03/2022, 17:09:00, 17:45:00
4	06/03/2022, 18:37:00, 19:09:00
5	06/03/2022, 19:24:00, 19:57:00
6	06/03/2022, 20:18:00, 20:45:00
7	06/04/2022, 14:10:00, 14:39:00

8	06/04/2022, 17:00:00, 18:45:00
9	06/04/2022, 19:04:00, 19:38:00
10	06/04/2022, 23:35:00, 00:15:00
11	06/05/2022, 15:20:00, 15:53:00
12	06/05/2022, 16:01:00, 16:44:00
13	06/05/2022, 16:55:00, 18:46:00
14	06/05/2022, 19:23:00, 19:57:00
15	06/05/2022, 20:07:00, 21:38:00
16	06/07/2022, 15:10:00, 15:46:00
17	06/07/2022, 16:52:00, 18:13:00
18	06/07/2022, 19:04:00, 20:00:00
19	06/07/2022, 20:02:00, 22:08:00
20	06/08/2022, 16:28:00, 17:22:00
21	06/08/2022, 17:45:00, 18:30:00
22	06/08/2022, 18:41:00, 19:39:00
23	06/08/2022, 19:51:00, 20:40:00
24	06/08/2022, 21:23:00, 22:30:00
25	06/09/2022, 18:50:00, 20:09:00
26	06/09/2022, 20:17:00, 21:21:00
27	06/09/2022, 21:37:00, 22:58:00
28	06/10/2022, 14:23:00, 15:43:00
29	06/10/2022, 15:50:00, 16:50:00
30	06/10/2022, 17:50:00, 20:17:00
31	06/10/2022, 21:20:00, 22:05:00
32	06/11/2022, 15:10:00, 16:04:00
33	06/11/2022, 16:08:00, 17:26:00
34	06/11/2022, 18:15:00, 19:45:00
35	06/11/2022, 20:45:00, 21:39:00
36	06/12/2022, 14:43:00, 15:22:00
37	06/12/2022, 15:48:00, 17:23:00
38	06/12/2022, 17:26:00, 18:32:00
39	06/12/2022, 19:14:00, 21:51:00
40	06/13/2022, 12:35:00, 13:21:00
41	06/13/2022, 13:26:00, 14:12:00
42	06/14/2022, 12:58:00, 13:34:00
43	06/14/2022, 13:37:00, 14:12:00
44	06/14/2022, 14:14:00, 14:55:00
45	06/14/2022, 14:59:00, 15:45:00
46	06/14/2022, 17:24:00, 17:35:00
47	07/02/2022, 18:36:00, 19:03:00
48	07/02/2022, 21:38:00, 22:25:00
49	07/03/2022, 15:45:00, 18:06:00

50	07/03/2022, 19:36:00, 20:21:00
51	07/04/2022, 15:15:00, 16:52:00
52	07/05/2022, 15:50:00, 16:55:00
53	07/05/2022, 17:18:00, 18:24:00
54	07/05/2022, 19:31:00, 21:00:00
55	07/06/2022, 15:47:00, 17:37:00
56	07/06/2022, 19:51:00, 20:32:00
57	07/06/2022, 20:47:00, 21:22:00
58	07/07/2022, 15:52:00, 16:26:00
59	07/07/2022, 18:01:00, 18:19:00
60	07/08/2022, 15:38:00, 16:57:00
61	07/08/2022, 17:52:00, 18:55:00
62	07/08/2022, 20:22:00, 21:50:00
63	07/09/2022, 19:15:00, 21:44:00
64	07/10/2022, 15:18:00, 17:08:00
65	07/10/2022, 18:31:00, 20:03:00
66	07/10/2022, 20:14:00, 21:34:00
67	07/11/2022, 14:24:00, 16:01:00
68	07/11/2022, 16:49:00, 18:04:00
69	07/11/2022, 18:26:00, 20:21:00
70	07/11/2022, 20:38:00, 21:22:00
71	07/12/2022, 15:22:00, 16:38:00
72	07/12/2022, 17:30:00, 19:36:00
73	07/13/2022, 14:39:00, 16:46:00
74	07/13/2022, 17:00:00, 18:09:00
75	07/13/2022, 21:58:00, 22:47:00
76	07/14/2022, 13:58:00, 15:50:00
77	07/14/2022, 16:13:00, 17:24:00
78	07/14/2022, 17:47:00, 18:17:00
79	08/02/2022, 14:02:00, 15:53:00
80	08/02/2022, 16:28:00, 17:31:00
81	08/02/2022, 18:42:00, 19:07:00
82	08/03/2022, 13:10:00, 14:59:00
83	08/04/2022, 13:37:00, 14:13:00
84	08/04/2022, 14:25:00, 15:05:00
85	08/04/2022, 15:29:00, 16:29:00
86	08/04/2022, 16:41:00, 17:14:00
87	08/04/2022, 17:30:00, 18:45:00
88	08/04/2022, 19:59:00, 21:37:00
89	08/04/2022, 21:40:00, 22:25:00
90	08/05/2022, 14:30:00, 16:16:00
91	08/05/2022, 16:17:00, 16:48:00

92	08/05/2022, 17:04:00, 17:36:00
93	08/05/2022, 18:02:00, 18:34:00
94	08/05/2022, 19:37:00, 21:06:00
95	08/06/2022, 15:00:00, 16:47:00
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97	08/06/2022, 22:00:00, 22:41:00
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110	08/11/2022, 17:46:00, 18:46:00
111	08/11/2022, 19:06:00, 19:58:00
112	08/12/2022, 14:20:00, 16:00:00
113	08/12/2022, 16:38:00, 16:59:00
114	08/13/2022, 13:44:00, 14:45:00
115	08/13/2022, 15:33:00, 15:52:00
116	08/13/2022, 17:27:00, 18:32:00
117	08/13/2022, 21:56:00, 23:02:00
118	08/14/2022, 13:59:00, 15:14:00
119	08/14/2022, 16:47:00, 17:34:00
120	08/14/2022, 18:38:00, 19:35:00
121	08/14/2022, 19:46:00, 21:17:00
122	09/02/2022, 15:21:00, 18:23:00
123	09/02/2022, 22:48:00, 00:40:00
124	09/03/2022, 15:29:00, 17:03:00
125	09/04/2022, 15:16:00, 16:37:00
126	09/04/2022, 17:10:00, 20:00:00
127	09/04/2022, 20:35:00, 22:10:00
128	09/05/2022, 15:30:00, 18:25:00
129	09/05/2022, 19:37:00, 21:00:00
130	09/05/2022, 21:34:00, 23:25:00
131	09/06/2022, 15:26:00, 16:35:00
132	09/06/2022, 20:47:00, 23:55:00
133	09/07/2022, 14:58:00, 17:59:00

134	09/07/2022, 18:39:00, 20:30:00
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136	09/09/2022, 14:52:00, 18:30:00
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138	09/10/2022, 14:57:00, 17:40:00
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142	09/12/2022, 13:37:00, 17:57:00
143	09/12/2022, 18:40:00, 20:00:00
144	09/13/2022, 14:19:00, 18:17:00
145	09/13/2022, 19:50:00, 21:03:00
146	09/14/2022, 14:06:00, 14:43:00
147	09/14/2022, 15:21:00, 16:40:00
148	09/14/2022, 18:04:00, 19:12:00
149	09/14/2022, 21:00:00, 21:30:00

Table S2. Ground-based measurements compared with the TBS measurements for the periods under different cluster influences.

	Cluster 1 - Marine		Cluster 2 - Mixed influence		Cluster 3 - Continental	
	Ground	TBS	Ground	TBS	Ground	TBS
T (C)	27.86±4.07	31.81±2.82	28.25±4.68	30.62±2.99	26.55±4.63	29.65±2.96
RH (%)	78.18±18.72	50.85±23.32	74.37±20.10	57.06±22.00	71.26±20.16	58.98±17.6
CPC ($\times 10^3 \text{ cm}^{-3}$)	2.21 $\pm$ 2.72	2.14±2.75	2.71 $\pm$ 2.44	3.77±3.20	6.87 $\pm$ 7.83	6.08±3.88
CCN (cm^{-3}) SS = 0.63%	647 $\pm$ 552	796±753	834 $\pm$ 819	1530±1490	2395 $\pm$ 2551	2379±1720

Table S3. TBS deployment overlaps with TAMU MPL operations during the TRACER

Date	Time (UTC)	Platform	Sampling location	Air mass
July 13, 2022	17:00 – 21:30	ARM lidar	AMF site	Mixture from Clusters 1 and 2
	14:39 – 22:47	TBS	ANC site	Cluster 1: Marine
August 8, 2022	16:29 – 18:47	TAMU MPL	Galveston	Cluster 1: Marine
	21:22 – 22:52	TAMU MPL	Hempstead	Cluster 2: Regional
	17:00 – 23:00	ARM lidar	AMF site	Cluster 1: Marine
	14:20 – 20:00	TBS	ANC site	Cluster 2: Regional
August 9, 2022	17:01 – 22:59	ARM lidar	AMF site	Cluster 1: Marine
	14:39 – 20:23	TBS	ANC site	Cluster 1: Marine

August 10, 2022	17:15 – 23:33	TAMU MPL	Bear Creek	Cluster 2: Regional
	17:00 – 22:59	ARM lidar	AMF site	Cluster 1: Marine
	13:31 – 17:30	TBS	ANC site	Cluster 1: Marine
September 6, 2022	16:55 – 20:53	TAMU MPL	Hockley	Cluster 2: Regional
	15:26 – 23:55	TBS	ANC site	Cluster 1: Marine
September 7, 2022	16:40 – 21:48	TAMU MPL	Hockley	Cluster 2: Regional
	14:58 – 21:19	TBS	ANC site	Cluster 2: Regional

Table S4: Acronyms table for this study.

TBS	Tethered Balloon System
TRACER	Tracking Aerosol Convection interactions ExpeRiment
CCN	Cloud Condensation Nuclei
CPC	Condensation Particle Counter
ARM	Atmosphere Radiation Measurement
AMF	ARM Mobile Facility
Tof-ACSM or ACSM	Time-of-Flight Aerosol Chemical Speciation Monitor
ACTIVATE	Aerosol Cloud meTeorology Interactions oVer the western ATlantic Experiment
IOP	Intensive Observation Period
ANC	Ancillary site
PWV	Precipitable Water Vapor
LWP	Liquid Water Path
NEXRAD	Next Generation Weather Radar
PPI	Plan Position Indicator
POPS	Portable Optical Particle Spectrometer
STAC	Size- and Time-Resolved Aerosol Collector
nano-DESI-HRMS	nanospray Desorption ElectroSpray Ionization High-Resolution Mass Spectrometry
PBLHT	Planetary Boundary Layer Height
MPL	MicroPulse Lidar
TAMU	Texas A&M University
HYSPLIT	Hybrid Single-Particle Lagrangian Integrated Trajectory
ECMWF	European Center for Medium-Range Weather Forecasts
PCA	Principal Component Analysis
CAPE	Convective Available Potential Energy

CIN	Convective Inhibition
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