



*Supplement of*

## **Aircraft-based observation of volatile organic compounds (VOCs) over the North China Plain**

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**Table S1.** The list of VOC species calibrated with standard gas. The limit of detections (LODs) and propagated uncertainties are listed as well.

VOC species	Ion formula	LODs (ppbv)	Uncertainties (%)
Methanol	$\text{CH}_4\text{OH}^+$	0.45	6%
Acetonitrile	$\text{C}_2\text{H}_3\text{NH}^+$	0.04	12%
Acetaldehyde	$\text{C}_2\text{H}_4\text{OH}^+$	0.10	6%
Ethanol	$\text{C}_2\text{H}_6\text{OH}^+$	2.46	14%
Acetone	$\text{C}_3\text{H}_6\text{OH}^+$	0.05	7%
Isoprene	$\text{C}_5\text{H}_8\text{H}^+$	0.07	11%
MVK&MACR*	$\text{C}_4\text{H}_6\text{OH}^+$	0.04	12%
MEK	$\text{C}_4\text{H}_8\text{OH}^+$	0.04	9%
Benzene	$\text{C}_6\text{H}_6\text{H}^+$	0.02	11%
Toluene	$\text{C}_7\text{H}_8\text{H}^+$	0.03	10%
Styrene	$\text{C}_8\text{H}_8\text{H}^+$	0.04	23%
C8 aromatics	$\text{C}_8\text{H}_{10}\text{H}^+$	0.02	14%
C9 aromatics	$\text{C}_9\text{H}_{12}\text{H}^+$	0.02	13%
C10 aromatics	$\text{C}_{10}\text{H}_{14}\text{H}^+$	0.04	18%
Monoterpenes	$\text{C}_{10}\text{H}_{16}\text{H}^+$	0.07	16%

\* Methyl vinyl ketone (MVK) and methacrolein (MACR) were measured as their sum by PTR-ToF-MS

19 **Table S2.** The heights of the planetary boundary layer (HPBL) of Beijing determined  
20 by the air parcel method during all the aerial surveys in Sep. 2017 and Jul. 2019 as  
21 discussed in Section 2.3. A 10% uncertainty is assigned to the results.

Date and time*	Aerial survey stage	HPBL (m)
2017/09/09 12:06-16:54	Ascending stage	1100
	Descending stage	1200
2017/09/12 12:16-16:10	Ascending stage	900
	Descending stage	1600
2017/09/13 13:35-16:55	Ascending stage	1000
	Descending stage	1400
2017/09/14 12:31-16:58	Ascending stage	850
	Descending stage	1300
2017/09/15 10:36-13:05	Ascending stage	450
	Descending stage	750
2019/07/14 9:41-12:18	Ascending stage	750
	Descending stage	1700

22 Note: \* Local times are listed for each flight.

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24 **Table S3.** The means and standard deviations of VOC concentrations during all aerial surveys in Sep. 2017 in ppb.

Species	Sep. 9, 2017	Sep. 12, 2017	Sep. 13, 2017	Sep. 14, 2017	Sep. 15, 2017
Methanol	7.51±6.74	4.29±2.35	10.86±9.92	10.42±9.51	9.92±10.17
Acetonitrile	0.26±0.14	0.30±0.06	0.43±0.16	0.38 ±0.17	0.35±0.13
Acetaldehyde	3.11±1.92	2.35±1.91	3.44±3.11	3.34±3.21	2.32±2.39
Ethanol	10.81±14.23	6.29±8.29	17.09±21.56	23.03±36.10	14.47±22.72
Acetone	4.01±2.16	3.23±1.12	5.70±3.98	4.99 ±3.15	4.23±1.87
Isoprene	0.92±0.96	1.63±0.93	2.22±1.29	2.03±1.46	4.25±0.51
MVK&MACR*	0.60±0.73	3.65±1.13	3.65±1.65	2.64±1.22	1.79±0.72
MEK	0.57±0.59	0.70±0.18	1.08±0.91	1.16±0.91	0.83±0.74
Benzene	0.46±0.38	0.20±0.37	0.61±0.66	0.49±0.52	0.43±0.41
Toluene	0.37±0.34	0.44±0.27	0.65±0.64	0.8 ±0.91	0.60±0.89
Styrene	0.28±0.20	0.09±0.13	0.07±0.08	0.08±0.09	0.06±0.08
C8 aromatics	0.62±0.55	0.63±0.37	1.20±2.33	1.24±1.96	1.13±1.95
C9 aromatics	0.34±0.19	0.55±0.20	0.59±0.33	0.48±0.42	0.41±0.34
C10 aromatics	0.3±0.22	0.34±0.14	0.29±0.15	0.25±0.15	0.22±0.14

Monoterpenes	0.19±0.17	1.34±0.23	0.95±0.24	0.71±0.21	0.59±0.18
Total VOCs	30.38±27.41	25.87±13.41	48.83±45.32	52.10±57.67	41.18±41.44

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26 \* Methyl vinyl ketone (MVK) and methacrolein (MACR) were measured as their sum by PTR-ToF-MS.

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28 **Table S4.** The means and standard deviations of VOC concentrations below the planetary boundary layer (PBL) during all aerial surveys in Sep.  
 29 2017 in ppb.

Species	Sep. 9, 2017	Sep. 12, 2017	Sep. 13, 2017	Sep. 14, 2017	Sep. 15, 2017	AVG±SD
Methanol	17.56±1.77	9.43±2.07	27.00±3.08	21.23±10.50	29.65±4.73	21.94±8.30
Acetonitrile	0.43±0.06	0.34±0.06	0.68±0.09	0.55±0.22	0.58±0.10	0.53±0.16
Acetaldehyde	5.28 ±0.66	5.26±4.35	8.79±1.56	6.69±4.42	6.91±1.34	6.66±2.86
Ethanol	32.82±7.98	22.84±7.76	54.34±8.33	62.52±51.91	59.07±14.46	46.74±26.38
Acetone	7.51±0.51	3.85±1.19	11.47±0.62	8.39±3.44	7.52±1.02	8.10±2.72
Isoprene	2.63 ±0.99	2.99±1.69	4.19±0.93	3.69±1.77	4.49±0.74	3.60±1.40
MVK&MACR*	1.94±0.48	6.03±2.11	6.59±1.22	4.03±1.28	3.07±0.67	4.10±2.18
MEK	1.58±0.36	1.11±0.22	2.63±0.41	2.21±0.99	2.29±0.34	2.02±0.72
Benzene	1.08±0.28	0.56±1.30	1.74±0.65	1.07±0.65	1.20±0.27	1.19±0.73
Toluene	0.93±0.17	0.94±0.63	1.81±0.28	1.88±1.13	2.37±0.47	1.59±0.80
Styrene	0.17±0.07	0.26±0.44	0.19±0.12	0.17±0.11	0.16±0.12	0.18±0.19
C8 aromatics	1.66±0.59	1.51±0.47	4.39±4.43	3.20±3.04	4.71±1.97	3.18±2.95
C9 aromatics	0.64±0.15	0.88±0.52	1.16±0.36	0.88±0.64	1.03±0.32	0.91±0.44

C10 aromatics	0.65±0.21	0.56±0.38	0.49±0.26	0.38±0.22	0.40±0.20	0.51±0.27
Monoterpenes	0.42±0.19	1.46±0.38	1.18±0.29	0.84±0.24	0.61±0.22	0.84±0.45

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31 \* Methyl vinyl ketone (MVK) and methacrolein (MACR) were measured as their sum by PTR-ToF-MS.

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33 **Table S5.** The means and standard deviations of VOC concentrations above the planetary boundary layer (PBL) during all aerial surveys in Sep.  
34 2017 in ppb.

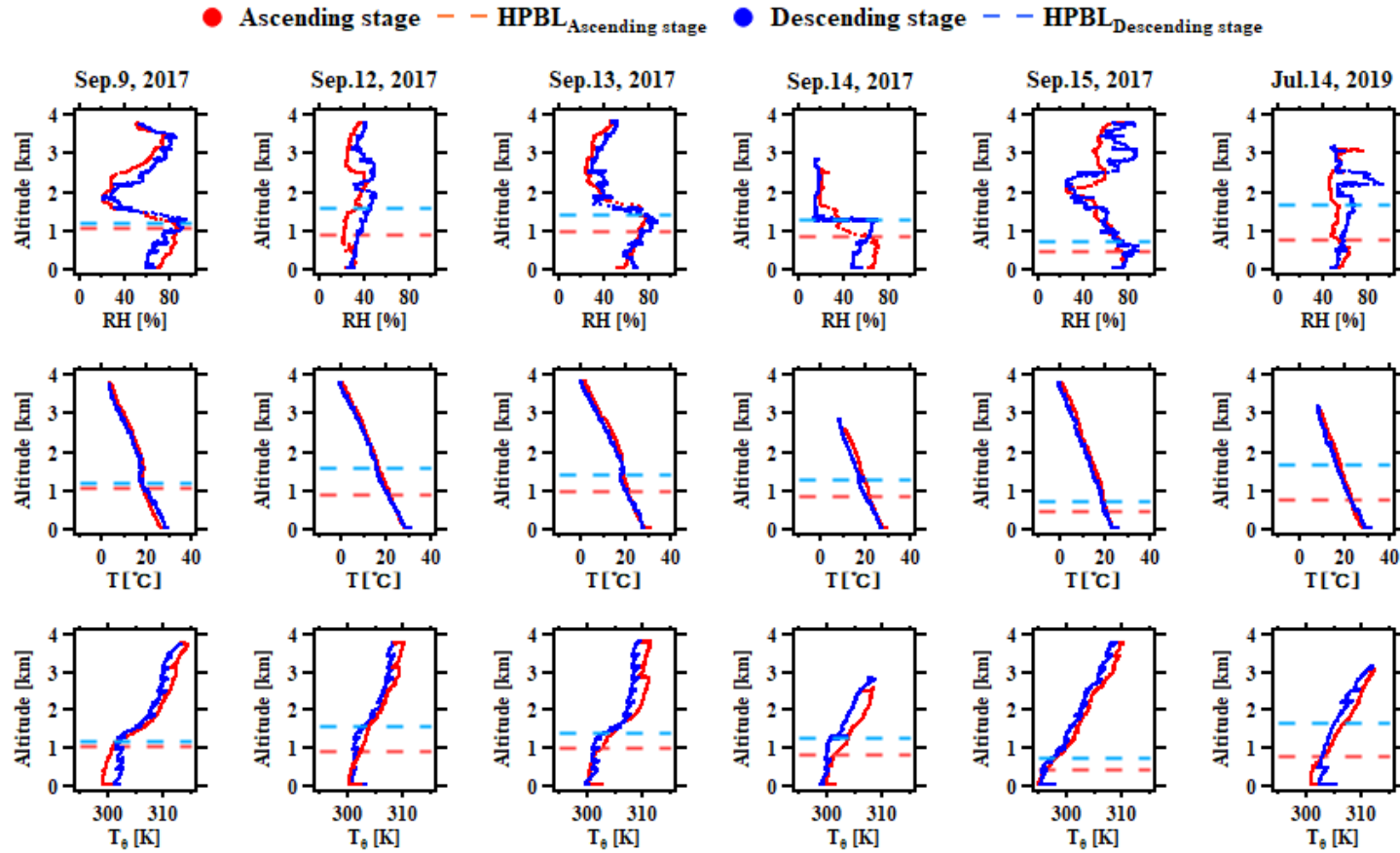
Species	Sep. 9, 2017	Sep. 12, 2017	Sep. 13, 2017	Sep. 14, 2017	Sep. 15, 2017	AVG±SD
Methanol	5.29±5.40	3.37±1.20	4.65±2.65	10.42±9.51	5.20±2.78	3.96±2.98
Acetonitrile	0.23±0.13	0.29±0.06	0.34±0.08	0.38±0.17	0.30±0.07	0.27±0.10
Acetaldehyde	2.62±1.79	1.99±1.31	1.56±0.88	3.3±3.214	1.24±0.72	1.85±1.37
Ethanol	5.73±9.94	2.82±0.91	3.57±2.83	23.03±36.10	3.90±2.79	2.84±1.80
Acetone	3.21±1.52	3.15±1.16	3.27±1.62	4.99±3.15	3.44±0.94	3.02±1.12
Isoprene	0.58±0.56	1.52±0.77	1.50±0.60	2.03±1.46	4.20±0.42	1.54±1.32
MVK&MACR*	0.32±0.43	3.31±0.60	2.68±0.39	2.64±1.22	1.49±0.24	1.84±1.36
MEK	0.34±0.38	0.63±0.09	0.52±0.21	1.16±0.91	0.48±0.17	0.44±0.22
Benzene	0.32±0.26	0.16±0.05	0.27±0.28	0.49±0.52	0.25±0.15	0.22±0.16
Toluene	0.25±0.22	0.36±0.07	0.26±0.10	0.85±0.91	0.18±0.09	0.24±0.12
Styrene	0.31±0.21	0.07±0.05	0.04±0.04	0.08±0.09	0.03±0.04	0.14±0.18
C8 aromatics	0.42±0.28	0.49±0.10	0.35±0.10	1.24±1.96	0.27±0.11	0.37±0.14
C9 aromatics	0.27±0.14	0.51±0.11	0.40±0.08	0.48±0.42	0.26±0.06	0.36±0.15



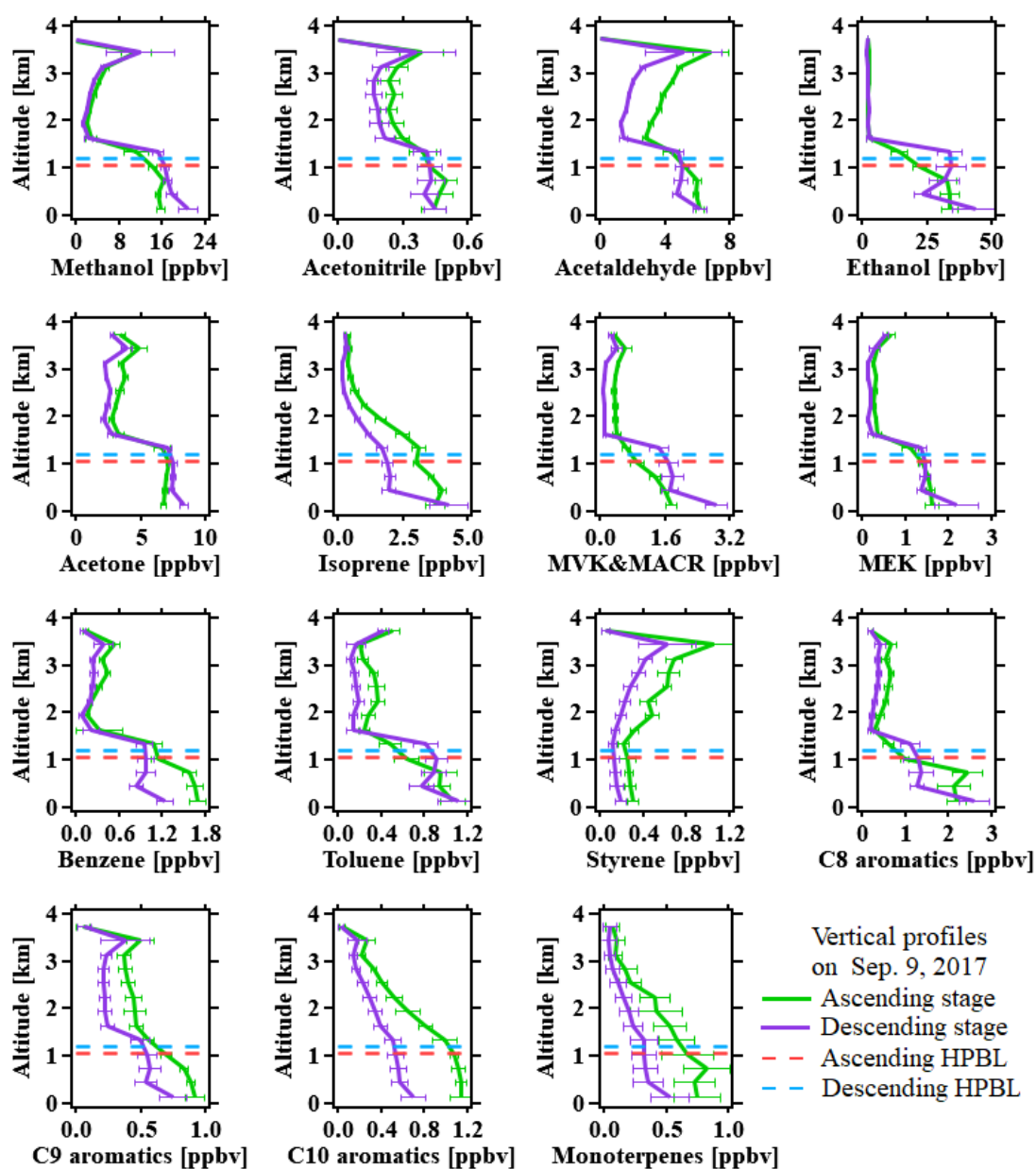
C10 aromatics	0.26±0.16	0.32±0.07	0.24±0.06	0.25±0.15	0.18±0.06	0.25±0.11
Monoterpenes	0.14±0.13	1.33±0.21	0.86±0.18	0.71±0.21	0.58±0.16	0.71±0.51

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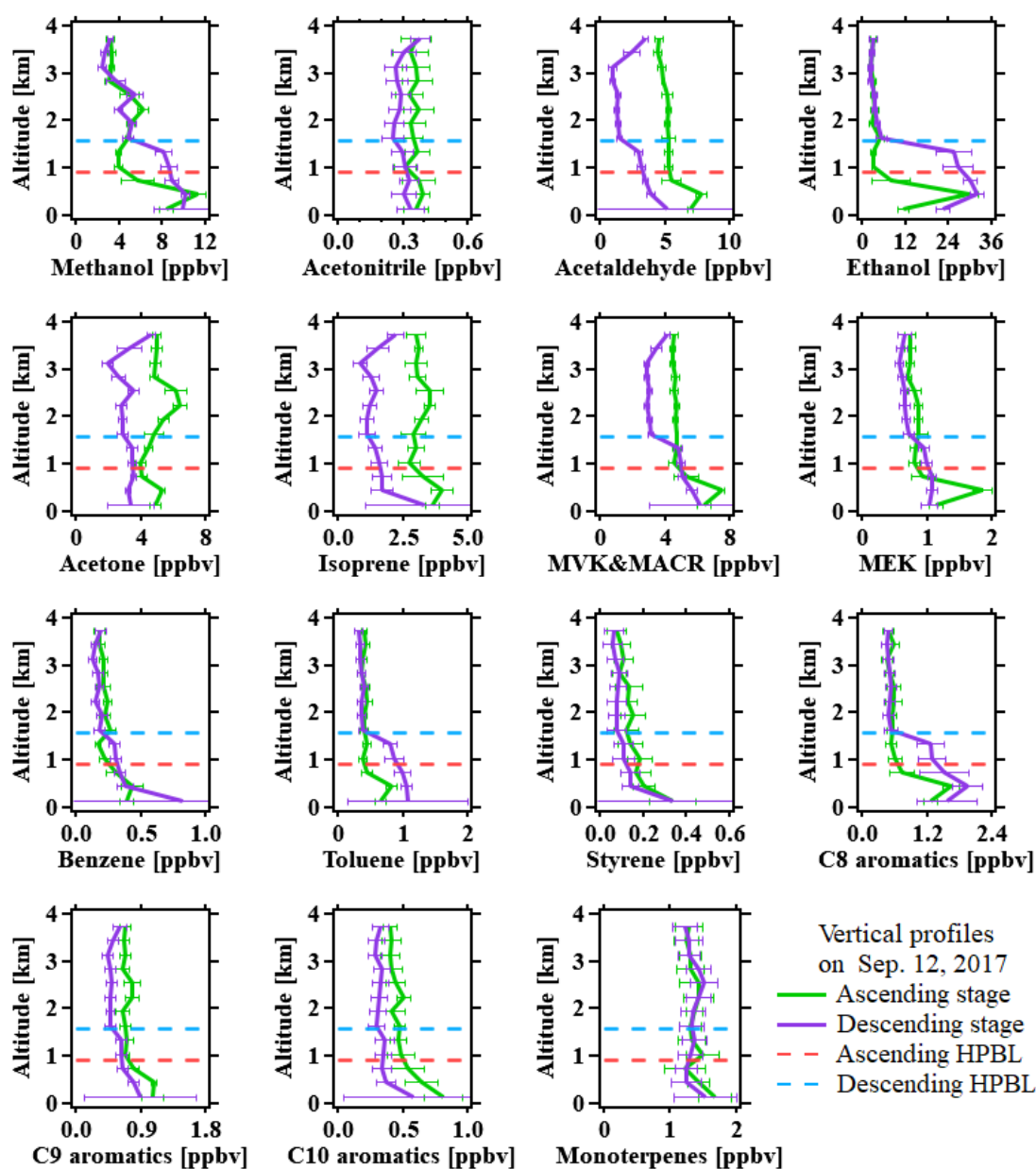
36 \* Methyl vinyl ketone (MVK) and methacrolein (MACR) were measured as their sum by PTR-ToF-MS.



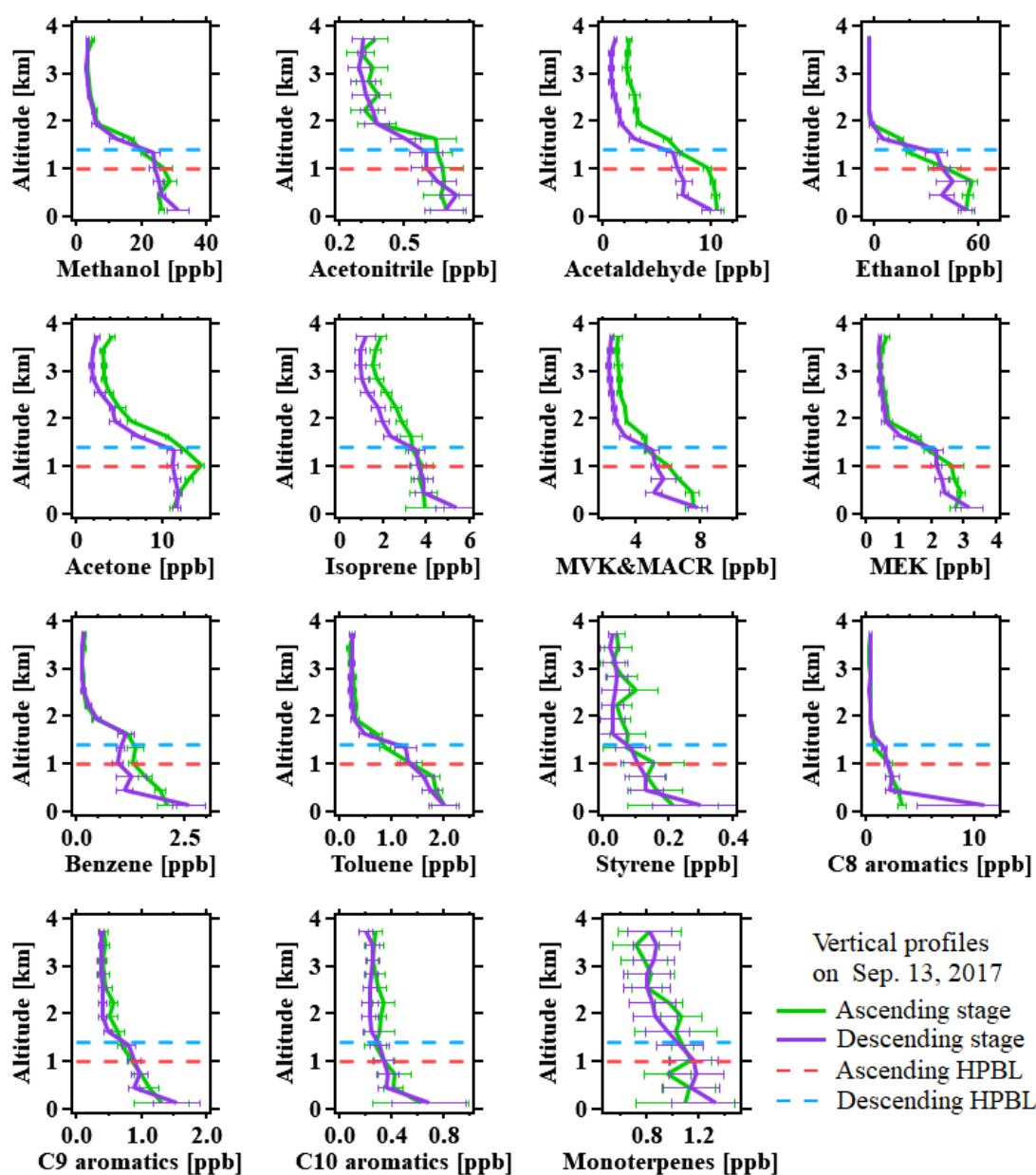
**Figure S1.** Vertical profiles of meteorological factors during Sep. 2017 and Jul. 2019 aerial surveys. The red and blue dots are the data measured during the ascending and descending stages, respectively. The red and blue dashed lines show the HPBL during the ascending and descending stages, respectively.



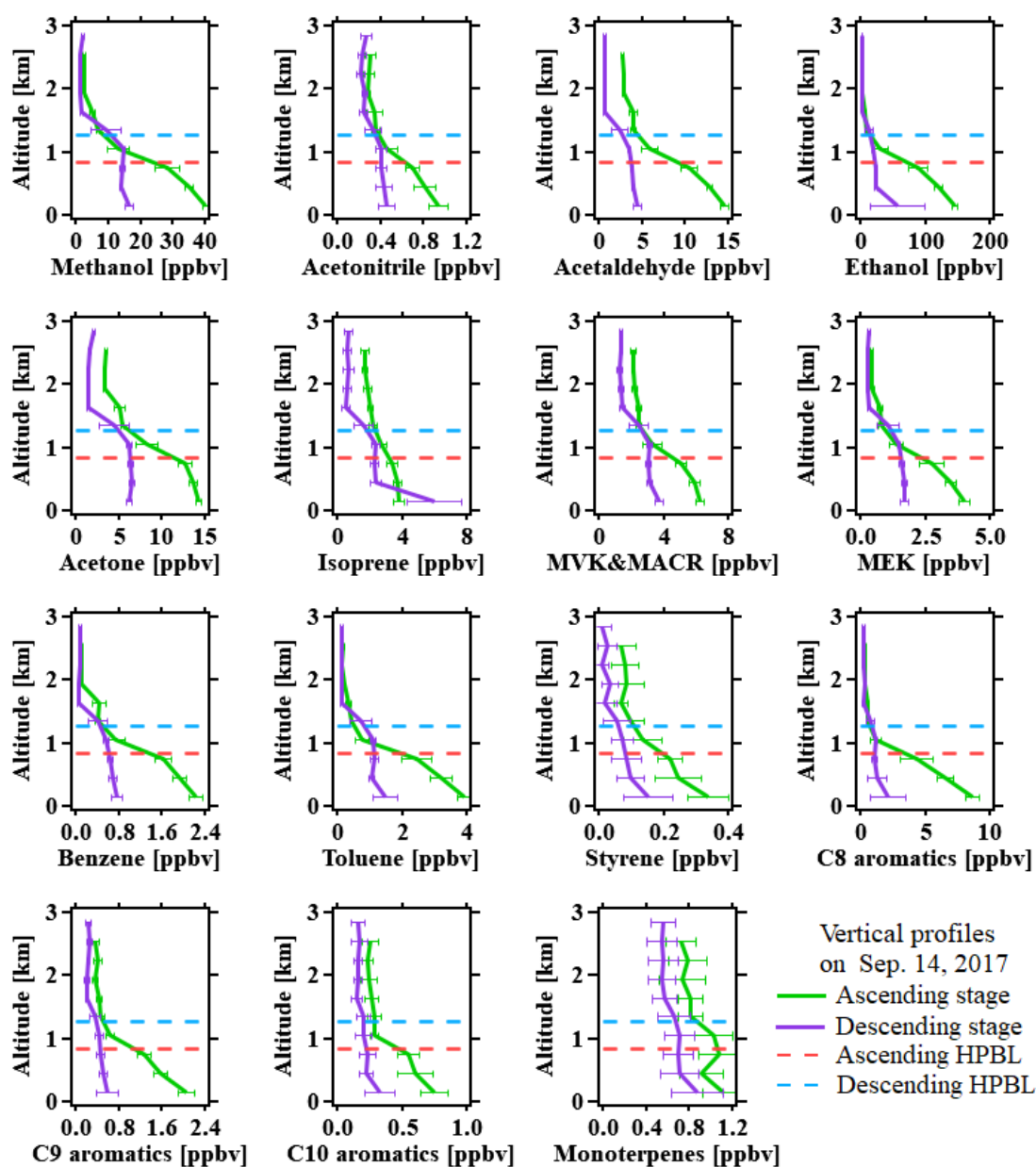
**Figure S2.** Vertical profiles of VOC mixing ratios during the ascending (in green) and descending stages (in purple) for the aerial survey on Sep.9<sup>th</sup>, 2017, with error bars. The red and blue dashed lines show the HPBL during the ascending and descending stages, respectively.



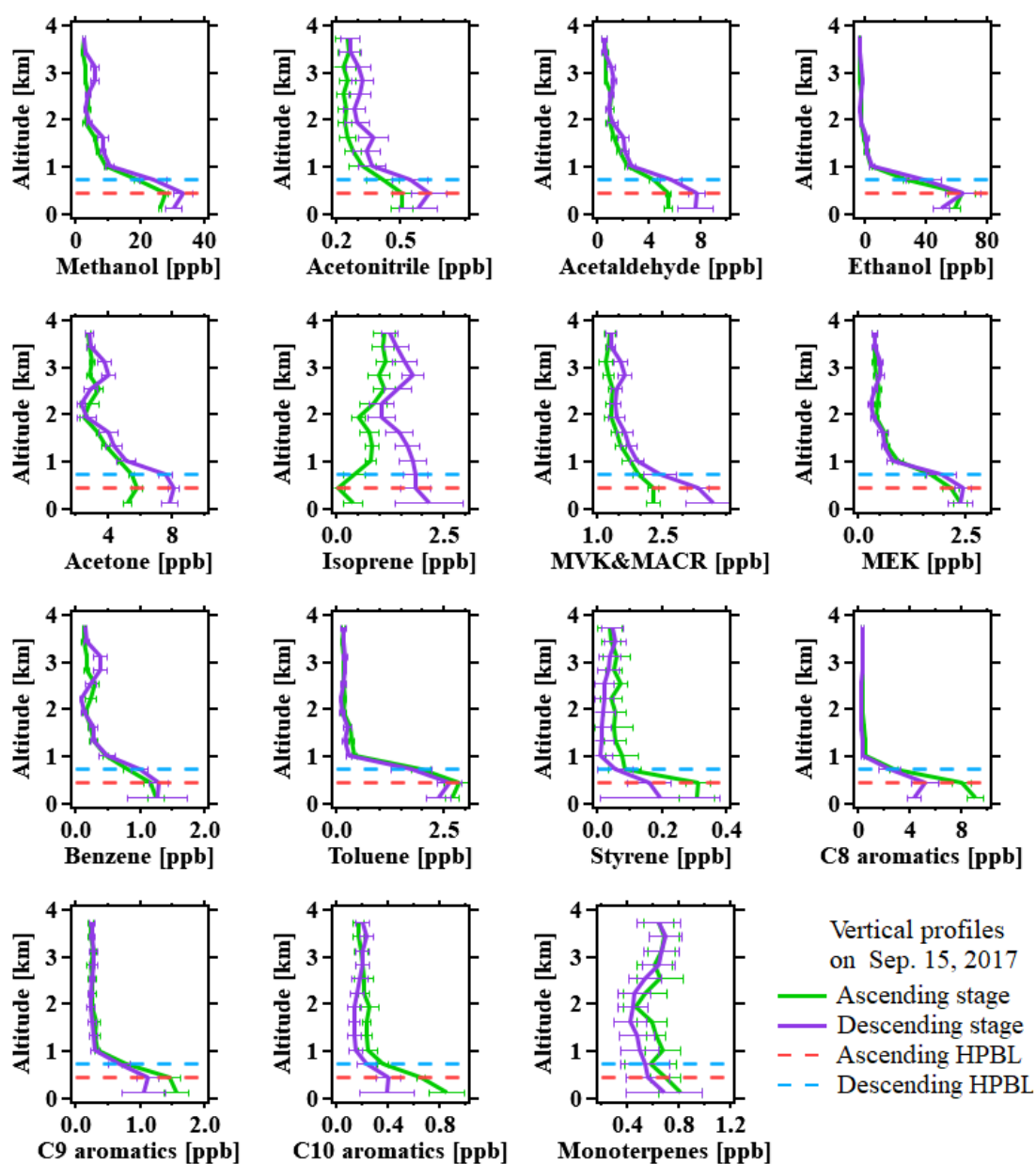
**Figure S3.** Vertical profiles of VOC mixing ratios during the ascending (in green) and descending stages (in purple) for the aerial survey on Sep.12<sup>th</sup>, 2017, with error bars. The red and blue dashed lines show the HPBL during the ascending and descending stages, respectively.



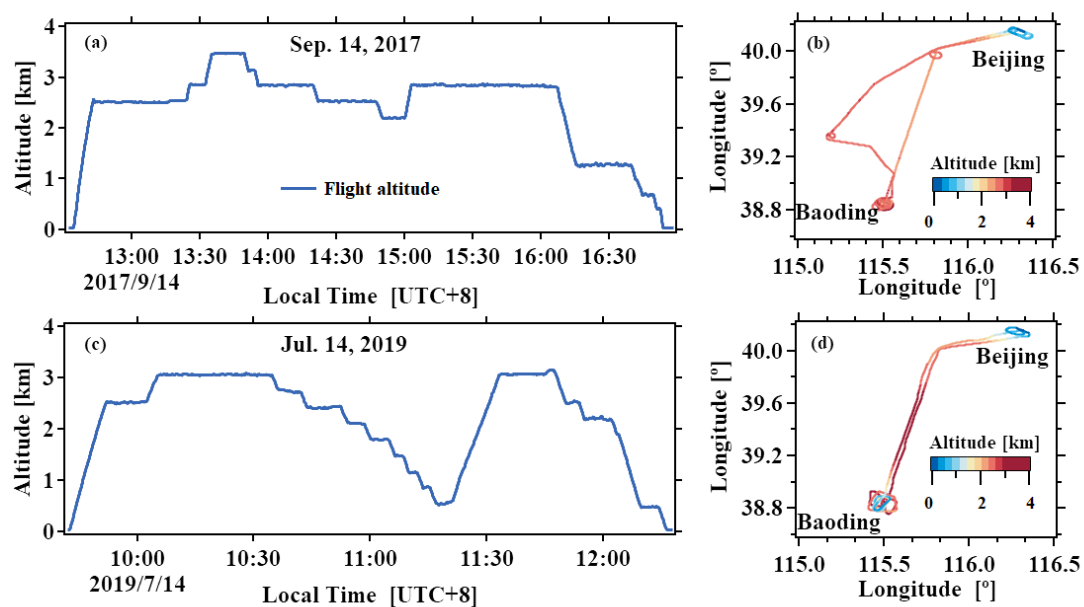
**Figure S4.** Vertical profiles of VOC mixing ratios during the ascending (in green) and descending stages (in purple) for the aerial survey on Sep.13<sup>th</sup>, 2017, with error bars. The red and blue dashed lines show the HPBL during the ascending and descending stages, respectively.



**Figure S5.** Vertical profiles of VOC mixing ratios during the ascending (in green) and descending stages (in purple) for the aerial survey on Sep.14<sup>th</sup>, 2017, with error bars. The red and blue dashed lines show the HPBL during the ascending and descending stages, respectively.

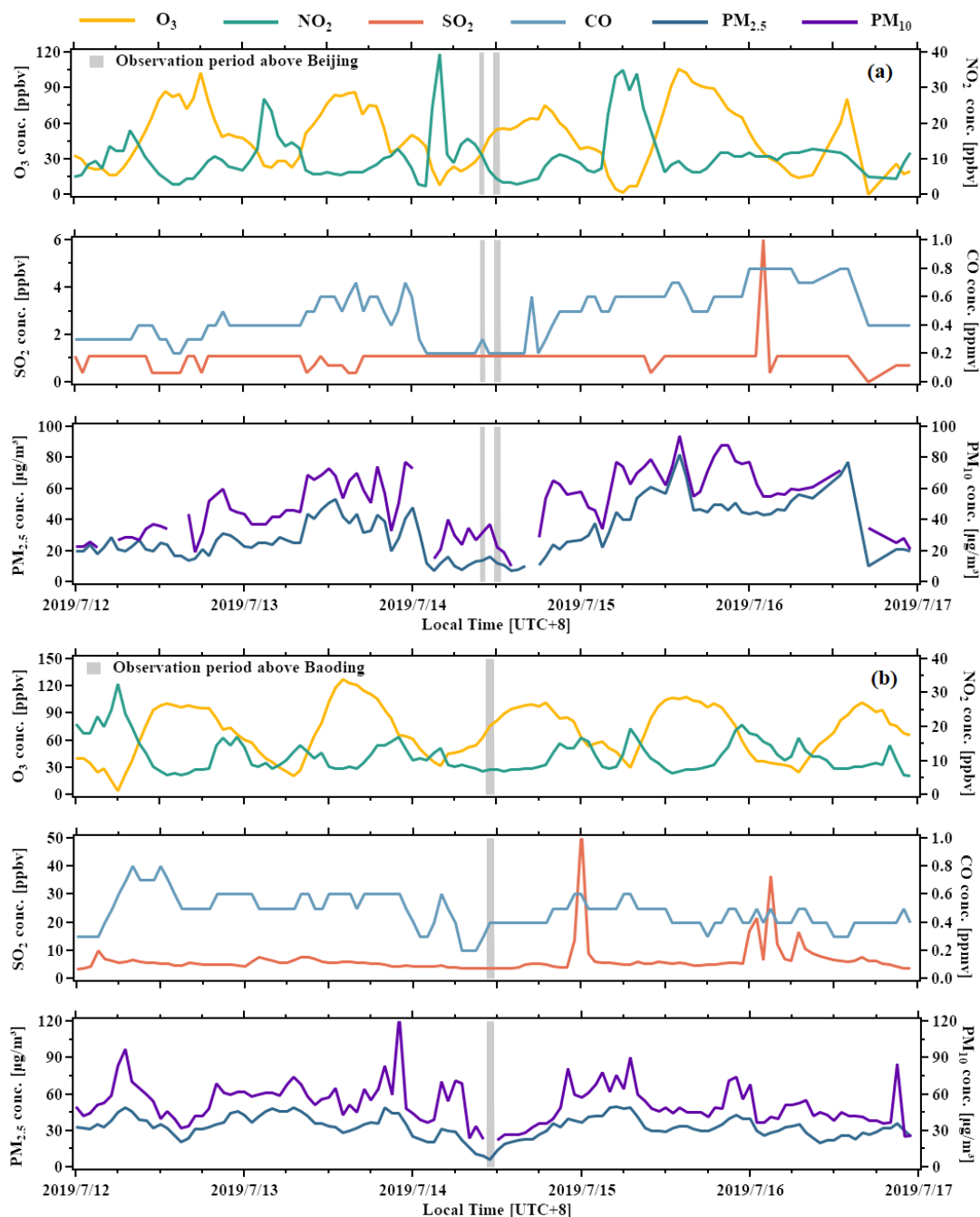


**Figure S6.** Vertical profiles of VOC mixing ratios during the ascending (in green) and descending stages (in purple) for the aerial survey on Sep.15<sup>th</sup>, 2017, with error bars. The red and blue dashed lines show the HPBL during the ascending and descending stages, respectively.

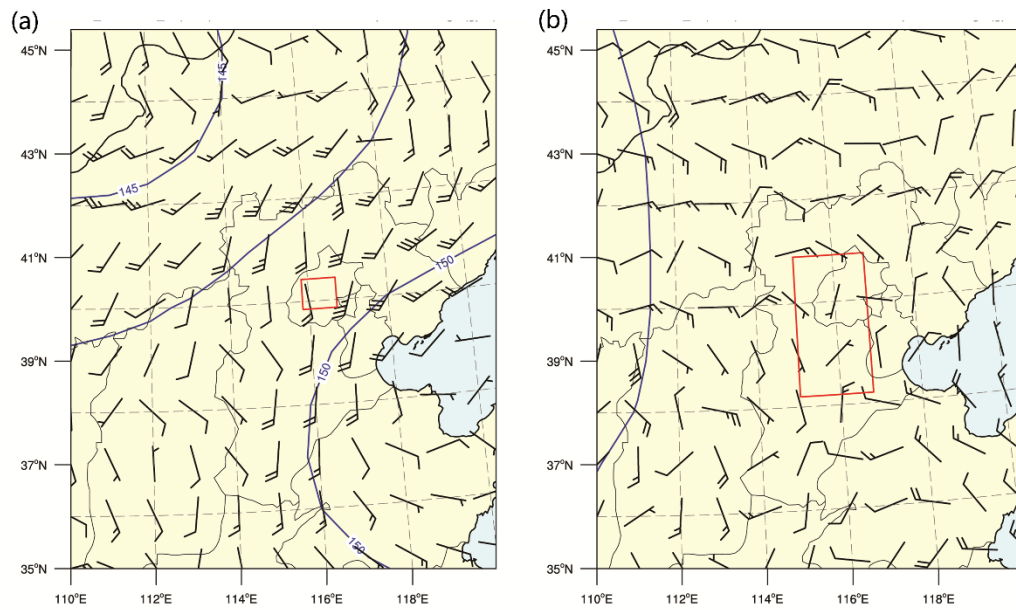


**Figure S7.** Time series of flight altitudes and flight routes on Sep.14<sup>th</sup>, 2017 (a, b) and Jul. 14<sup>th</sup>, 2019 (c, d). The flight routes are color-coded with altitudes.





**Figure S8.** Time series of criteria pollutants including ozone, NO<sub>2</sub>, SO<sub>2</sub>, CO, PM<sub>2.5</sub>, and PM<sub>10</sub> from Jul. 12<sup>th</sup> to 16<sup>th</sup>, 2019 over Beijing (a) and Baoding (b). Data is obtained from the Beijing Changping Town station and the Baoding natatorium station, the closest national air quality monitoring stations to the flight trajectories. Grey shaded areas indicate the observation periods. According to the Level-II threshold of the National Ambient Air Quality Standards (NAAQS), continuous exceedances from Jul. 12<sup>th</sup> to 16<sup>th</sup>, 2019 were observed covering both Beijing and Baoding.



**Figure S9.** The synoptic charts for the flight measurements on Sep. 9<sup>th</sup>, 2017 (a) and Jul. 14<sup>th</sup>, 2019 (b). The wind field at 850 hpa was plotted. The red box indicates the area covering the trajectory of each flight as shown in Figure 1 (Route 1 and Route 6). The meteorology data were downloaded from the Global Forecast System (<https://www.ncei.noaa.gov/products/weather-climate-models/global-forecast>).