Supplement of

Development of multi-channel whole-air sampling equipment onboard unmanned aerial vehicle for investigating VOCs vertical distribution in the planetary boundary layer

Suding Yang et al.

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Table S1. Linearity (R^2), minimum detection limit (MDL), and precision (relative standard deviation, RSD) of measured parameters.

Species	R^2	MDL (ppbv)	RSD (n=5)	Species	R^2	MDL (ppbv)	RSD (n=5)
Alkanes				toluene	0.999	0.006	0.8%
ethane	1.000	0.037	1.3%	ethylbenzene	0.995	0.003	0.7%
propane	0.998	0.032	1.1%	m/p-xylene	0.998	0.004	0.5%
isobutane	0.999	0.016	1.2%	o-xylene	0.999	0.003	0.5%
n-Butane	1.000	0.025	1.2%	styrene	0.998	0.003	0.9%
cyclopentane	0.999	0.008	0.3%	isopropylbenzene	1.000	0.008	0.6%
isopentane	0.996	0.007	1.2%	n-propylbenzene	1.000	0.003	1.3%
n-Pentane	0.999	0.007	1.4%	3-ethyltoluene	0.999	0.005	1.0%
2,2-dimethylbutane	0.999	0.011	0.6%	4-ethyltoluene	1.000	0.006	0.8%
2,3-dimethylbutane	1.000	0.005	0.3%	1,3,5-trimethylbenzene	0.999	0.002	1.8%
2-methylpentane	1.000	0.009	0.7%	2-ethyltoluene	1.000	0.004	1.5%
3-methylpentane	0.999	0.006	0.5%	1,2,4-trimethylbenzene	0.999	0.006	1.3%
n-hexane	0.999	0.004	0.4%	1,2,3-trimethylbenzene	0.999	0.006	1.4%
2,4-dimethylpentane	0.998	0.003	1.0%	1,3-diethylbenzene	0.999	0.006	2.3%
methylcyclopentane	1.000	0.002	1.1%	1,4-diethylbenzene	0.996	0.005	2.4%
2-methylhexane	1.000	0.002	0.7%	**OVOCs**			
cyclohexane	1.000	0.004	1.0%	acetaldehyde	0.997	0.043	3.7%
2,3-dimethylpentane	0.999	0.015	0.5%	acrolein	0.996	0.012	2.4%
3-methylhexane	1.000	0.013	1.1%	propanal	0.999	0.030	1.8%
2,2,4-trimethylpentane	0.999	0.003	1.0%	acetone	0.999	0.033	1.7%
n-heptane	0.999	0.009	0.6%	MTBE	0.997	0.013	2.7%
methylcyclohexane	1.000	0.003	0.8%	methacrolein	0.999	0.008	3.2%
2,3,4-trimethylpentane	0.996	0.003	0.3%	n-butanal	0.999	0.011	1.9%
2-methylheptane	0.990	0.005	1.2%	methylvinylketone	0.999	0.018	2.1%
3-methylheptane	0.990	0.009	1.0%	methylethylketone	1.000	0.019	0.8%
octane	0.991	0.005	1.3%	2-pentanone	1.000	0.012	3.5%
n-nonane	0.999	0.007	1.3%	n-pentanal	1.000	0.021	4.1%
n-decane	1.000	0.009	1.5%	3-pentanone	1.000	0.020	2.2%
undecane	0.995	0.008	1.7%	n-hexanal	0.999	0.015	1.6%
dodecane	0.992	0.011	2.4%	**Nitrile**			
Alkenes				Acetonitrile	0.998	0.039	1.3%
ethylene	0.999	0.039	0.6%	**Halocarbons**			
propene	1.000	0.018	0.9%	Freon114(C2F4Cl2)	0.999	0.006	1.2%
trans-2-Butene	0.999	0.009	1.1%	Chloromethane	1.000	0.020	2.1%
1-Butene	1.000	0.020	1.6%	Vinylchloride	0.997	0.023	1.2%
cis-2-Butene	1.000	0.008	0.8%	Bromomethane	0.995	0.024	1.1%
1,3-Butadiene	0.998	0.014	0.5%	Chloroethane	0.995	0.021	1.7%
1-pentene	1.000	0.009	1.0%	Freon11(CFCl3)	0.998	0.014	1.3%
trans-2-pentene	0.999	0.009	0.9%	Freon113(C2F3Cl3)	0.998	0.016	1.2%
isoprene	0.999	0.010	0.5%	1,1-Dichloroethylene	1.000	0.017	2.0%
cis-2-pentene	0.999	0.006	0.6%	Dichloromethane	1.000	0.014	0.6%
1-hexene	0.998	0.005	0.4%	1,1-Dichloroethane	1.000	0.014	0.3%
Alkyne				cis-1,2Dichloroethylene	1.000	0.009	0.7%
acetylene	0.999	0.039	0.4%	Chloroform	1.000	0.015	0.6%
Aromatics				1,1,1-Trichloroethane	0.999	0.016	0.6%
benzene	0.998	0.004	0.8%	carbontetrachloromethane	0.998	0.020	0.5%

Table S1 continued.

Species	R^2	MDL (ppbv)	RSD (n=5)	Species	R^2	MDL (ppbv)	RSD (n=5)
1,2-Dichloroethane	0.999	0.021	0.3%	Chlorobenzene	0.999	0.042	1.1%
tran-1,3-Dichloropropene	1.000	0.017	1.2%	1,3-Dichlorobenzene	0.999	0.021	0.5%
cis-1,3-Dichloropropene	0.999	0.017	1.1%	1,4-Dichlorobenzene	0.999	0.017	0.9%
1,1,2-Trichloroethane	0.999	0.009	0.9%	Benzylchloride	0.999	0.021	1.3%
1,2-Dibromoethane	0.998	0.011	1.3%	1,2-Dichlorobenzene	0.999	0.050	0.7%
1,2-Dichloropropane	0.999	0.011	0.7%	Trichloroethylene	1.000	0.014	0.9%

Table S2. Adsorption loss and 7-day recovery of VOC species.

VOC species		Adsorption loss* (%)	Ambient sample in Quartz			Ambient sample in SUMMA			Standard gas in Quartz		
			0 day (ppbv)	7 day (ppbv)	recovey rate	0 day (ppbv)	7 day (ppbv)	recovey rate	0 day (ppbv)	7 day (ppbv)	recovey rate
Alkanes	ethane	1.3	2.515	2.483	98.7%	5.556	5.465	98.4%	2.040	2.046	100.3%
	propane	0.8	0.987	1.050	106.4%	1.475	1.527	103.5%	1.994	2.015	101.0%
	isobutane	-0.7	0.209	0.203	97.1%	0.310	0.312	100.6%	1.922	2.079	108.2%
	n-butane	0.3	0.273	0.275	100.7%	0.425	0.462	108.7%	2.054	2.056	100.1%
	cyclopentane	-0.8	0.048	0.046	95.8%	0.034	0.033	97.1%	2.109	2.054	97.4%
	isopentane	-0.2	0.141	0.135	95.7%	0.230	0.219	95.2%	2.024	2.096	103.6%
	n-pentane	-1.5	0.092	0.097	105.4%	0.164	0.163	99.4%	1.962	1.937	98.7%
	2,2-dimethylbutane	0	0.008	0.007	87.5%	0.012	0.011	91.7%	1.973	1.914	97.0%
	2,3-dimethylbutane	1.8	0.093	0.078	83.9%	0.108	0.093	86.1%	2.001	1.897	94.8%
	2-methylpentane	-1.9	0.061	0.053	86.9%	0.070	0.066	94.3%	2.055	1.995	97.1%
	3-methylpentane	-2.7	0.043	0.043	100.0%	0.047	0.048	102.1%	1.954	2.085	106.7%
	n-pentane	1.6	0.048	0.046	95.8%	0.034	0.033	97.1%	2.109	1.954	92.7%
	n-hexane	-0.7	0.068	0.073	107.4%	0.073	0.074	101.4%	2.129	2.090	98.1%
	2,4-dimethylpentane	-0.3	-	-	-	0.008	0.007	87.5%	2.100	1.815	86.4%
	methylcyclopentane	1.3	0.043	0.042	97.7%	0.047	0.046	97.9%	2.112	2.087	98.9%
	2-methylhexane	1.5	0.027	0.023	85.2%	0.022	0.018	81.8%	2.192	1.922	87.7%
	cyclohexane	1.2	0.032	0.029	90.6%	0.026	0.023	88.5%	2.074	1.942	93.6%
	2,3-dimethylpentane	2.8	-	-	-	-	-	-	1.968	1.813	92.1%
	3-methylhexane	0.7	0.015	0.013	86.7%	0.023	0.020	87.0%	2.012	1.888	93.8%
	2,2,4-trimethylpentane	1.3	0.013	0.014	107.7%	0.017	0.015	88.2%	2.103	1.996	94.9%
	n-heptane	2.4	0.023	0.019	82.6%	0.031	0.030	96.8%	2.039	1.866	91.5%
	methylcyclohexane	-0.5	0.019	0.019	100.0%	0.021	0.023	109.5%	1.954	1.910	97.8%
	2,3,4-trimethylpentane	1.1	0.005	0.005	100.0%	-	-	-	1.976	2.087	105.6%
	2-methylheptane	-0.3	-	-	-	0.015	0.012	80.0%	1.997	2.035	101.9%
	3-methylheptane	-1.3	-	-	-	-	-	-	2.016	1.994	98.9%
	octane	0.4	-	-	-	-	-	-	2.017	2.058	102.0%
	n-nonane	-0.8	0.020	0.018	90.0%	0.035	0.031	88.6%	2.152	1.982	92.1%
	n-decane	-0.5	0.017	0.016	94.1%	0.278	0.259	93.2%	2.162	1.994	92.2%
	undecane	1.1	0.102	0.095	93.1%	0.082	0.068	82.9%	1.931	1.884	97.6%
	dodecane	1.8	-	-	-	0.143	0.128	89.5%	2.119	1.907	90.0%
Alkenes	ethylene	0.6	0.694	0.660	95.1%	1.478	1.391	94.1%	2.051	1.990	97.1%
	propene	1.2	0.204	0.188	92.2%	0.263	0.258	98.1%	2.031	1.985	97.8%
	trans-2-butene	1.1	0.011	0.010	90.9%	0.008	0.007	87.5%	2.125	1.986	93.5%
	1-butene	-1.5	0.040	0.041	102.5%	0.034	0.032	94.1%	2.029	1.917	94.5%
	cis-2-Butene	1	-	-	-	-	-	-	1.925	1.803	93.7%
	trans-2-pentene	-2.1	0.003	0.0026	86.7%	-	-	-	1.964	2.026	103.2%
	isoprene	-0.1	0.026	0.024	92.3%	0.038	0.031	81.6%	1.910	1.803	94.4%
	cis-2-pentene	-0.3	-	-	-	0.079	0.061	77.2%	2.018	2.088	103.5%
	1-hexene	-0.4	0.017	0.013	76.5%	0.009	0.007	77.8%	2.163	2.010	92.9%
	1,3-butadiene	-0.8	0.015	0.014	93.3%	0.021	0.019	90.5%	2.066	1.903	92.1%
	acetylene	-0.5	0.541	0.534	98.7%	1.206	1.233	102.2%	2.025	2.045	101.0%
Aromatic	benzene	0.3	0.105	0.111	105.7%	0.148	0.145	98.0%	2.044	2.000	97.8%
	toluene	-1.4	0.170	0.167	98.2%	0.231	0.225	97.4%	2.121	2.020	95.2%
	ethylbenzene	-1.1	0.041	0.045	109.8%	0.061	0.059	96.7%	2.150	2.130	99.1%
	m/p-xylene	1.2	0.134	0.130	97.0%	0.188	0.179	95.2%	2.127	1.944	91.4%

	o-xylene	2.8	0.050	0.049	98.0%	0.070	0.073	104.3%	2.060	2.066	100.3%
	styrene	-1.6	0.016	0.013	81.3%	0.035	0.030	85.7%	2.017	1.965	97.4%
	isopropylbenzene	-1.3	-	-	-	0.015	0.014	93.3%	2.087	2.024	97.0%
	n-propylbenzene	1.2	0.008	0.007	87.5%	0.028	0.026	92.9%	2.184	1.985	90.9%
	3-ethyltoluene	-0.8	0.014	0.012	85.7%	-	-	-	1.929	1.989	103.1%
	4-ethyltoluene	1.2	-	-	-	0.044	0.037	84.1%	1.922	1.837	95.6%
	1,3,5-trimethylbenzene	0.9	0.008	0.007	87.5%	-	-	-	2.128	2.099	98.6%
	2-ethyltoluene	-2.1	0.018	0.018	100.0%	0.026	0.027	103.8%	1.906	2.040	107.0%
	1,2,4-trimethylbenzene	1.9	0.020	0.018	90.0%	0.051	0.046	90.2%	2.152	2.089	97.1%
	1,2,3-trimethylbenzene	-2.6	-	-	-	-	-	-	2.130	2.136	100.3%
	1,3-diethylbenzene	-2.4	-	-	-	0.033	0.035	106.1%	2.157	2.009	93.1%
	1,4-diethylbenzene	-3.8	0.011	0.009	81.8%	0.051	0.046	90.6%	2.158	1.981	91.8%
OVOCs	MTBE	1.3	0.040	0.034	85.0%	0.059	0.054	91.5%	1.928	1.998	103.6%
	acetaldehyde	-2.3	0.582	0.497	85.4%	0.437	0.372	85.1%	2.012	2.089	103.9%
	acrolein	-2.9	0.019	0.016	84.2%	0.064	0.056	87.5%	2.000	1.815	90.7%
	propanal	-4.4	0.187	0.191	102.1%	0.101	0.089	88.1%	2.165	1.889	87.2%
	acetone	-3.4	3.216	2.456	76.4%	1.453	1.140	78.5%	1.996	1.972	98.8%
	acetonitrile	-2.3	0.048	0.046	95.8%	0.074	0.074	100.0%	1.971	1.942	98.5%
	methacrolein	-2.9	0.044	0.041	93.2%	0.012	0.013	108.3%	2.149	2.077	96.7%
	n-butanal	-1.9	0.124	0.110	88.7%	0.058	0.053	91.4%	2.136	1.929	90.3%
	methylvinylketone	2.3	0.061	0.054	88.5%	0.028	0.025	89.3%	2.114	1.982	93.8%
	methylethylketone	-0.5	0.104	0.097	93.3%	0.090	0.081	90.0%	2.171	1.946	89.6%
	2-pentanone	-1.2	0.018	0.018	100.0%	-	-	-	2.008	2.008	100.0%
	n-pentanal	1.7	0.144	0.151	104.9%	0.034	0.032	94.1%	1.962	2.033	103.6%
	3-pentanone	-1.4	-	-	-	-	-	-	1.998	1.816	90.9%
	n-hexanal	-0.7	0.593	0.582	98.1%	0.151	0.132	87.4%	2.132	1.952	91.6%
Halocarbons	Freon114	-1.2	0.010	0.010	100.0%	0.013	0.013	100.0%	1.983	2.008	101.3%
	Chloromethane	2.3	0.283	0.281	99.3%	0.403	0.414	102.7%	1.947	1.904	97.8%
	Vinylchloride	-1.9	-	-	-	-	-	-	2.061	2.047	99.3%
	Bromomethane	1.6	-	-	-	-	-	-	2.007	2.008	100.0%
	Chloroethane	-3.8	-	-	-	-	-	-	2.018	1.917	95.0%
	Freon11	-1.7	0.145	0.155	106.9%	0.179	0.188	105.0%	2.017	2.026	100.4%
	Freon113	-0.4	0.043	0.039	90.7%	0.057	0.055	96.5%	2.051	2.080	101.4%
	1,1-Dichloroethylene	2.5	-	-	-	-	-	-	2.103	2.058	97.9%
	Dichloromethane	0.5	0.283	0.270	95.4%	0.327	0.351	107.3%	2.020	2.088	103.4%
	1,1-Dichloroethane	-0.3	0.034	0.032	94.1%	0.023	0.021	91.3%	2.170	2.089	96.3%
	cis-1,2Dichloroethylene	0.8	-	-	-	-	-	-	2.195	2.177	99.2%
	Chloroform	-1.5	0.299	0.289	96.7%	0.120	0.131	109.2%	1.986	1.985	100.0%
	1,1,1-Trichloroethane	-1.4	-	-	-	-	-	-	1.970	2.096	106.4%
	carbon tetrachloride	-0.7	0.047	0.046	97.9%	0.066	0.066	100.0%	2.062	2.081	100.9%
	1,2-Dichloroethane	0.8	0.137	0.147	107.3%	0.111	0.121	109.0%	1.984	1.928	97.2%
	Trichloroethylene	-1.1	-	-	-	-	-	-	1.891	1.880	99.5%
	1,2-Dichloropropane	-0.7	0.020	0.018	90.0%	0.027	0.026	96.3%	1.997	2.082	104.3%
	tran-1,3-Dichloropropene	1.2	-	-	-	-	-	-	2.171	2.148	98.9%
	1,1,2-Trichloroethane	-0.9	-	-	-	0.009	0.010	111.1%	2.186	2.265	103.6%

	cis-1,3-Dichloropropene	2.2	-	-	-	-	-	-	1.989	1.923	96.7%
	1,2-Dibromoethane	-1.3	-	-	-	-	-	-	2.180	2.124	97.4%
	Chlorobenzene	0	0.013	0.013	100.0%	-	-	-	1.932	2.010	104.1%
	1,3-Dichlorobenzene	-2.5	-	-	-	0.017	0.017	100.0%	1.908	1.894	99.2%
	1,4-Dichlorobenzene	1.3	0.042	0.036	109.5%	0.033	0.035	106.1%	1.973	1.999	101.3%
	Benzylchloride	2.1	-	-	-	-	-	-	2.011	1.981	98.5%
	1,2-Dichlorobenzene	-2.4	-	-	-	-	-	-	2.088	1.999	95.7%

*: Adsorption loss = (with sampler – direct injection) / direct injection
-: Detection limit not exceeded

Table S3. Information of regulatory instruments used for comparison experiments.

Parameters	Model	Measure method	Temporal resolution
O_3	49iQ	ultraviolet absorption	1min
NO_2	42i-D	chemiluminescence	5min
CO	48iQ	infrared absorption	5min
SO_2	43iQ	ultraviolet fluorescence	1min

Table S4. Execution time and boundary layer height for each mission.

Flight	Date	flight period	PBLH (m)	Flight	Date	flight period	PBLH (m)
1	Dec. 22	06:36-07:04	74	14	Dec. 30	07:25-07:51	53
2	Dec. 22	10:15-10:41	196	15	Dec. 30	10:26-10:52	208
3	Dec. 22	13:52-14:18	673	16	Dec. 30	14:05-14:32	474
4	Dec. 22	16:18-16:43	582	16	Dec. 30	16:11-16:37	496
5	Dec. 22	19:25-19:52	81	18	Dec. 30	18:22-18:48	147
6	Dec. 28	07:16-07:43	152	19	Jan. 4	07:41-08:08	69
7	Dec. 28	10:35-11:01	334	20	Jan. 4	10:35-11:01	334
8	Dec. 28	13:46-14:13	558	21	Jan. 4	14:22-14:54	965
9	Dec. 28	19:28-19:54	144	22	Jan. 4	18:31-18:59	168
10	Dec. 29	06:59-07:27	53	23	Jan. 5	07:32-07:59	64
11	Dec. 29	10:54-11:21	207	24	Jan. 5	10:26-10:52	202
12	Dec. 29	14:32-14:59	869	25	Jan. 5	14:06-14:32	812
13	Dec. 29	19:03-19:27	89	26	Jan. 5	18:28-18:54	207

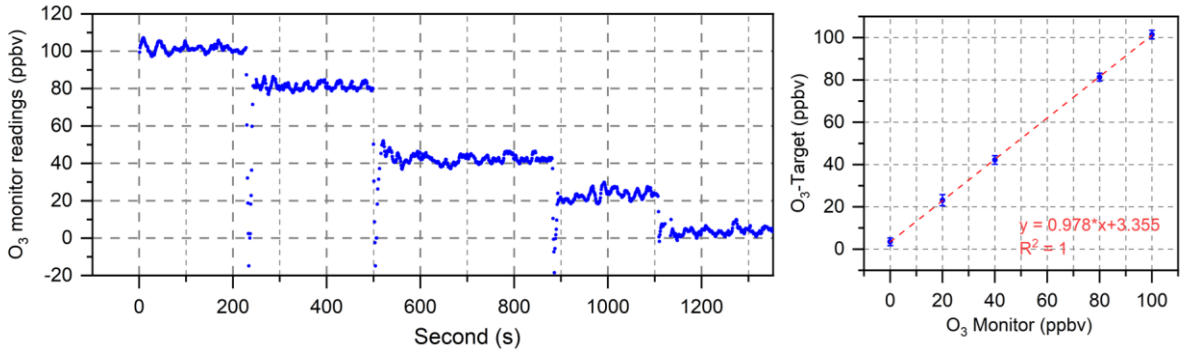

Figure S1. Calibration results of the ozone monitor.

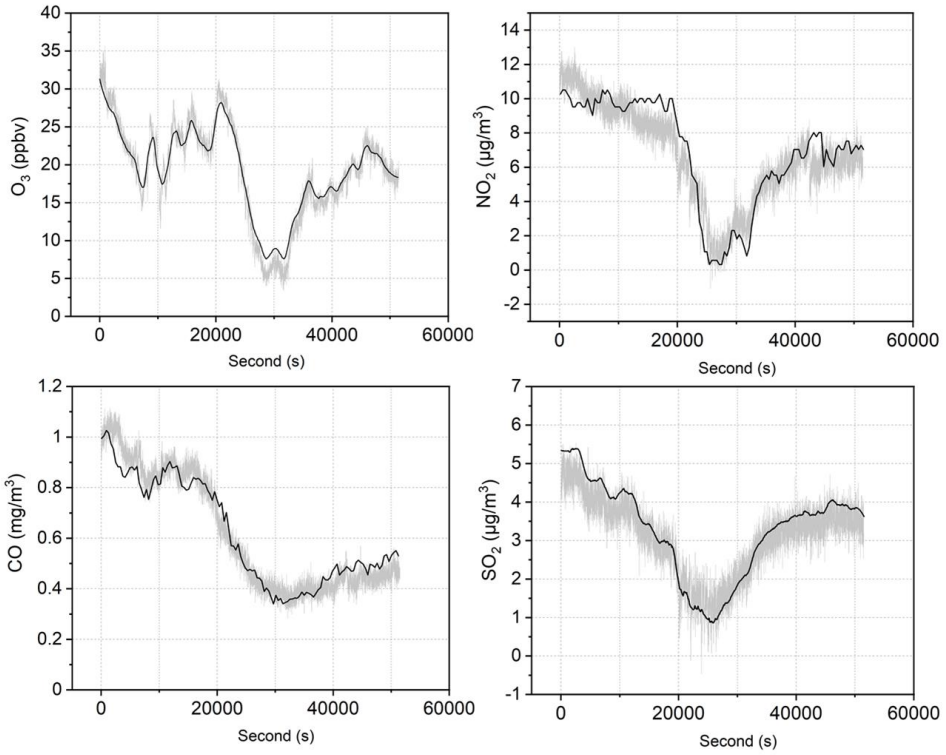

Figure S2. Comparison measurement results of ozone monitor and electrochemical sensor with regulatory instruments.

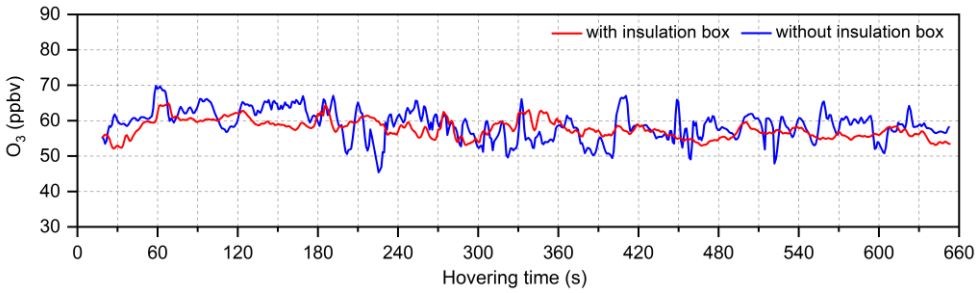

Figure S3. Volatility of readings from the ozone monitor with/without the insulation box.

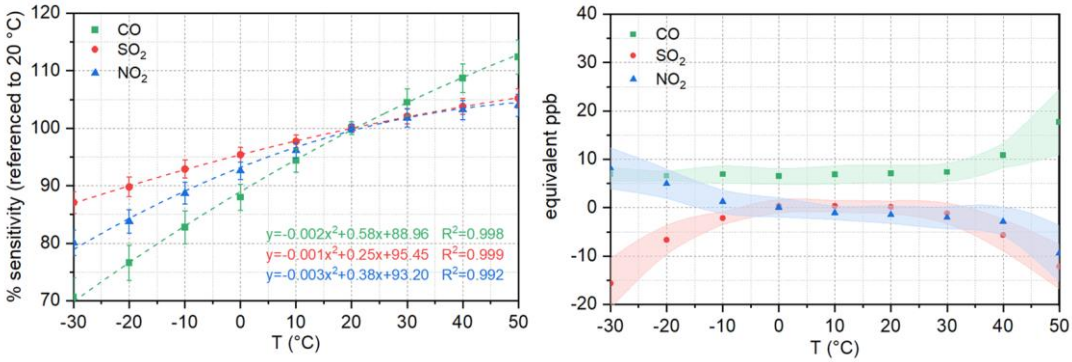

Figure S4. Left: Influence of temperature change on the measurement results of the sensor. Right: Influence of temperature change on the sensor's null point.

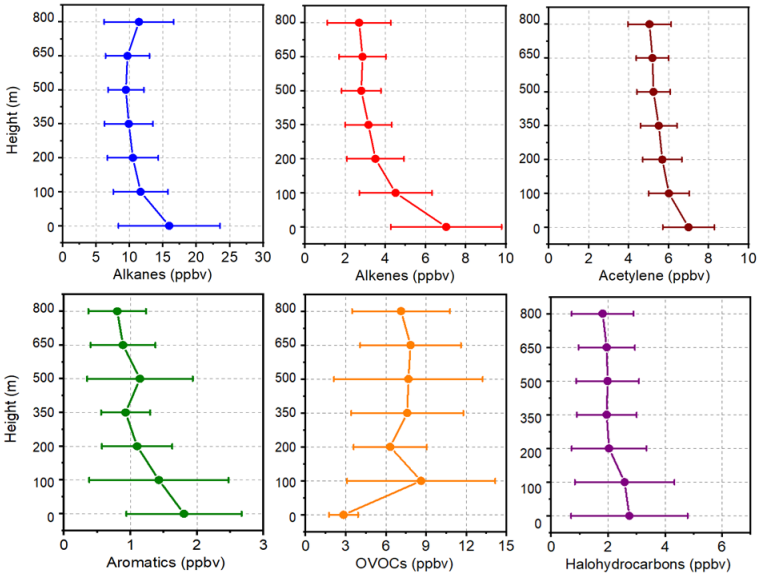

Figure S5. Vertical profiles of different VOC groups in field experiment (average results of all samples).