Supplmentary Material

List of Table and Figures

Table S1: Descriptive statistics of VOCs measured at rural background site in Cyprus from 2022-2024

Species	Species Name	Protonated Molar Mass	Group	Mean	Median	SD	SE	LB	UB	95th Percentile	Minimum	Maximum
CH_4O	Methanol	33.033	Alcohol	3.08	2.861	1.707	0.017	3.046	3.114	5.994	0.138	27.824
C_3H_4	Propyne	41.039	Aliphatic	0.257	0.194	0.213	0.002	0.253	0.261	0.649	0.022	4.612
C2H3N	Acetonitrile	42.039	N	0.117	0.111	0.038	0	0.116	0.118	0.194	0.041	0.325
C_3H_6	Propylene	43.054	Aliphatic	0.257	0.208	0.185	0.002	0.253	0.261	0.626	0.019	2.073
C_2H_4O	Acetaldehyde	45.033	Carbonyls	0.883	0.54	0.888	0.009	0.866	0.9	2.964	0.123	6.756
CH_3NO	Formamide	46.029	N	0.063	0.042	0.052	0.001	0.062	0.064	0.186	0.017	0.353
CH_2O_2	Formic Acid	47.013	Acids	0.78	0.421	0.93	0.009	0.762	0.798	2.667	0.022	7.994
C_2H_6O	Ethanol	47.049	Alcohol	0.433	0.353	0.349	0.004	0.425	0.44	1.074	0.009	3.683
C_4H_2	1,3-Butadiyne	51.044	Aliphatic	0.243	0.18	0.177	0.002	0.24	0.247	0.612	0.014	1.364
C_2H_3NO	Hydroxyacetonitrile	58.029	N	0.009	0.008	0.006	0	0.009	0.009	0.021	0.003	0.046
C_3H_6O	Acetone	59.049	Carbonyls	2.348	2.115	1.186	0.012	2.325	2.371	4.547	0.429	10.818
$C_2H_4O_2$	Acetic Acid	61.028	Acids	1.253	0.68	1.553	0.016	1.221	1.286	4.275	0.039	12.542
CClN	Cyanogen Chloride	61.979	N	0.004	0.003	0.002	0	0.004	0.004	0.008	0.002	0.014
C_2H_6S	Dimethyl Sulfide	63.044	S	0.064	0.044	0.059	0.001	0.063	0.065	0.181	0.005	0.554
C_5H_6	Cyclopentadiene	67.054	Aliphatic	0.012	0.01	0.007	0	0.012	0.012	0.026	0.003	0.081
C_4H_4O	Furan	69.033	Oxygenated	0.014	0.01	0.011	0	0.013	0.014	0.038	0.004	0.159
C_5H_8	Isoprene	69.07	Terpenes	0.155	0.094	0.183	0.002	0.151	0.158	0.521	0.005	2
C_4H_6O	MVK/Methacrolein	71.049	Oxygenated	0.08	0.056	0.072	0.001	0.079	0.082	0.24	0.003	0.529
$C_2H_5N_3$	Ethyl azide	72.056	N	0.008	0.006	0.006	0	0.008	0.008	0.02	0.002	0.048
C_4H_8O	Methyl Ethyl Ketone	73.065	Oxygenated	0.362	0.29	0.268	0.003	0.357	0.368	0.818	0.007	2.781
$C_2H_3NO_2$	Nitroethylene	74.024	N	0.007	0.006	0.004	0	0.007	0.007	0.015	0.002	0.03
$C_3H_6O_2$	Propionic Acid	75.044	Acids	0.21	0.131	0.222	0.002	0.206	0.215	0.712	0.01	1.545

$C_2H_4O_3$	Peracetic Acid	77.023	Acids	0.046	0.038	0.032	0	0.045	0.047	0.116	0.004	0.24
$C_3H_8O_2$	Propylene glycol	77.06	Alcohol	0.073	0.051	0.058	0.001	0.071	0.074	0.185	0.005	0.463
C_6H_6	Benzene	79.054	Aromatics	0.165	0.135	0.106	0.001	0.163	0.167	0.386	0.018	1.087
C_5H_5N	Pyridine	80.049	N	0.008	0.008	0.004	0	0.008	0.008	0.016	0.002	0.036
C_6H_8	Cycloheaxdiene	81.071	Aliphatic	0.23	0.184	0.184	0.002	0.226	0.234	0.546	0.016	2.101
C_6H_9	Cyclopentenyl Carbenium	82.078	Aromatics	0.016	0.013	0.012	0	0.016	0.016	0.038	0.002	0.139
$C_4H_4O_2$	2(3H)-Furanone	85.028	Carbonyls	0.018	0.01	0.021	0	0.018	0.019	0.061	0.003	0.2
C_5H_8O	Cyclopentanone	85.065	Carbonyls	0.029	0.017	0.034	0	0.029	0.03	0.099	0.002	0.296
C_4H_7NO	Methacrylamide	86.06	N	0.004	0.003	0.004	0	0.004	0.004	0.012	0.001	0.035
$C_4H_6O_2$	2,3-Butanedione	87.044	Carbonyls	0.087	0.051	0.09	0.001	0.085	0.089	0.282	0.003	0.634
$C_5H_{10}O$	Pentanal	87.08	Carbonyls	0.044	0.026	0.05	0.001	0.043	0.045	0.153	0.004	0.374
$C_3H_4O_3$	Pyruvic Acid	89.023	Acids	0.009	0.006	0.008	0	0.009	0.009	0.023	0.002	0.077
$C_4H_8O_2$	Methyl Carbonate	89.06	Oxygenated	0.04	0.029	0.034	0	0.039	0.041	0.114	0.003	0.264
C_7H_8	Toluene	93.07	Aromatics	0.096	0.07	0.098	0.001	0.094	0.098	0.243	0.005	1.302
C_6H_6O	Phenol	95.049	Aromatics	0.018	0.01	0.027	0	0.018	0.019	0.055	0.005	0.491
C_7H_{10}	1,3-Cycloheptadiene	95.086	Aliphatic	0.023	0.018	0.019	0	0.023	0.023	0.058	0.003	0.245
$C_5H_4O_2$	Furfural	97.028	Carbonyls	0.021	0.007	0.036	0	0.02	0.022	0.092	0.002	0.394
$C_4H_2O_3$	Maleic anhydride	99.008	Oxygenated	0.016	0.012	0.017	0	0.016	0.017	0.044	0.003	0.221
$C_4H_4O_3$	Succinic anhydride	101.023	Oxygenated	0.019	0.011	0.019	0	0.018	0.019	0.06	0.003	0.276
$C_5H_8O_2$	Acetylacetone	101.06	Carbonyls	0.104	0.043	0.17	0.002	0.1	0.107	0.459	0.004	1.363
$C_6H_{12}O$	Hexanal	101.096	Carbonyls	0.017	0.01	0.02	0	0.016	0.017	0.059	0.002	0.145
$C_4H_6O_3$	Propylene Carbonate	103.039	Oxygenated	0.014	0.008	0.015	0	0.014	0.014	0.048	0.002	0.098
C_7H_5N	Benzonitrile	104.049	N	0.004	0.004	0.003	0	0.004	0.004	0.008	0.001	0.064
C_7H_4O	Ethynyl cyclopentadienone	105.033	Carbonyls	0.006	0.004	0.005	0	0.006	0.006	0.018	0.002	0.041

C_8H_8	Styrene	105.07	Aromatics	0.019	0.015	0.014	0	0.018	0.019	0.043	0.002	0.142
$C_3H_6O_4$	Glyceric acid	107.03		0.014	0.009	0.018	0	0.014	0.015	0.042	0.002	0.217
C_8H_{10}	Xylene	107.086	Aromatics	0.062	0.029	0.119	0.001	0.06	0.065	0.229	0.003	1.764
C_7H_9N	Dimethyl+Ethyl Pyridine	108.081	N	0.006	0.004	0.008	0	0.006	0.007	0.018	0.001	0.125
$C_7H_{10}O$	2,3-dimethyl-2-cyclopentenone	111.08	Oxygenated	0.016	0.01	0.019	0	0.016	0.016	0.052	0.002	0.201
$C_5H_7NO_2$	Ethyl cyanoacetate	114.055	N	0.006	0.004	0.005	0	0.006	0.006	0.016	0.002	0.038
$C_6H_{10}O_2$	C6 dicarbonyl, caprolactone	115.075	Oxygenated	0.055	0.029	0.076	0.001	0.054	0.057	0.2	0.003	0.653
$C_4H_4O_4$	Maleic Acid	117.018	Acids	0.01	0.005	0.016	0	0.01	0.01	0.039	0.002	0.22
$C_5H_8O_3$	Methyl acetoacetate	117.055	Oxygenated	0.009	0.004	0.013	0	0.009	0.01	0.036	0.002	0.148
$C_4H_6O_4$	Butanedioic acid	119.034	Acids	0.014	0.008	0.016	0	0.014	0.014	0.047	0.002	0.142
$C_6H_{14}S$	1-(Methylthio)pentane	119.089	S	0.006	0.004	0.005	0	0.006	0.006	0.017	0.001	0.061
C_9H_{12}	Trimethylbenzene	121.101	Aromatics	0.045	0.017	0.096	0.001	0.043	0.047	0.189	0.002	1.316
C_9H_{14}	Santene	123.117	Aliphatic	0.008	0.005	0.01	0	0.008	0.009	0.025	0.002	0.111
$C_7H_{10}O_2$	Methylsorbate	127.075	Oxygenated	0.019	0.011	0.021	0	0.019	0.02	0.068	0.004	0.172
$C_7H_{12}O_2$	Cyclohexanecarboxylic acid	129.091	Acids	0.014	0.009	0.015	0	0.014	0.014	0.042	0.002	0.151
$C_6H_{10}O_3$	Ethyl acetoacetate	131.07		0.008	0.004	0.01	0	0.008	0.008	0.029	0.001	0.085
$C_{10}H_{14}$	Butylbenzene	135.117	Aromatics	0.02	0.014	0.022	0	0.02	0.021	0.058	0.002	0.295
$C_9H_{13}N$	Amphetamine	136.112	N	0.004	0.002	0.003	0	0.003	0.004	0.01	0.001	0.05
$C_5H_4N_4O$	Hypoxanthine	137.046	N	0.006	0.004	0.006	0	0.006	0.006	0.016	0.001	0.049
$C_{10}H_{16}$	Monoterpenes	137.132	Terpenes	0.335	0.269	0.269	0.003	0.33	0.341	0.795	0.026	3.008
$C_9H_{15}N$	Triallylamine	138.128	N	0.014	0.011	0.011	0	0.013	0.014	0.033	0.001	0.11
$C_9H_{14}O$	Isophorone	139.112	Carbonyls	0.031	0.023	0.026	0	0.031	0.032	0.082	0.002	0.341

$C_7H_{16}O_3$	Dipropylene glycol monomethyl ether	149.117	Oxygenated	0.004	0.003	0.005	0	0.004	0.004	0.012	0.001	0.08
$C_{10}H_{14}O$	D-Verbenone	151.112	Oxygenated	0.01	0.006	0.011	0	0.009	0.01	0.031	0.001	0.163
$C_{10}H_{16}O$	2,4-Decadienal	153.127	Carbonyls	0.012	0.008	0.011	0	0.011	0.012	0.03	0.001	0.178
$C_8H_{15}N_3$	Impetamine	154.134	N	0.002	0.001	0.002	0	0.002	0.002	0.005	0.001	0.027
$C_7H_6O_2$	Benzoic acid	123.044	Acids	0.011	0.006	0.011	0	0.01	0.011	0.035	0.003	0.088
C_3H_4O	Acrolein	57.033	Oxygenated	0.203	0.118	0.229	0.002	0.198	0.207	0.715	0.01	1.933
$C_2H_2O_2$	Glyoxal	59.013	Oxygenated	0.074	0.07	0.042	0.001	0.073	0.076	0.126	0.019	1.22
CH_4SO_3	Methansulfonic acid	96.995	S	0.009	0.008	0.003	0	0.009	0.009	0.015	0.005	0.042

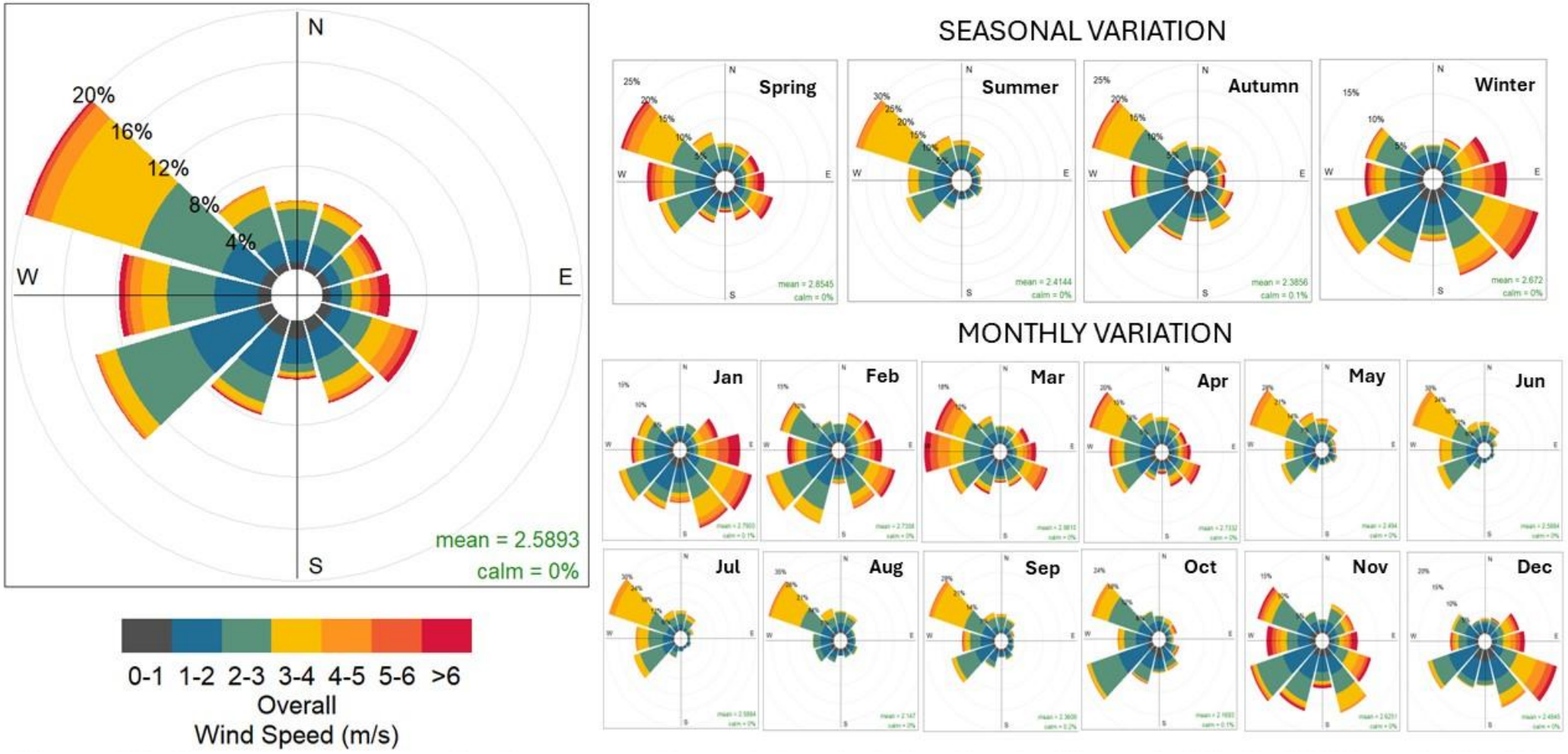

Figure S1: Windrose diagrams showing frequency of counts by wind direction for the period April 2022- June 2024 at the rural background site of Cyprus.

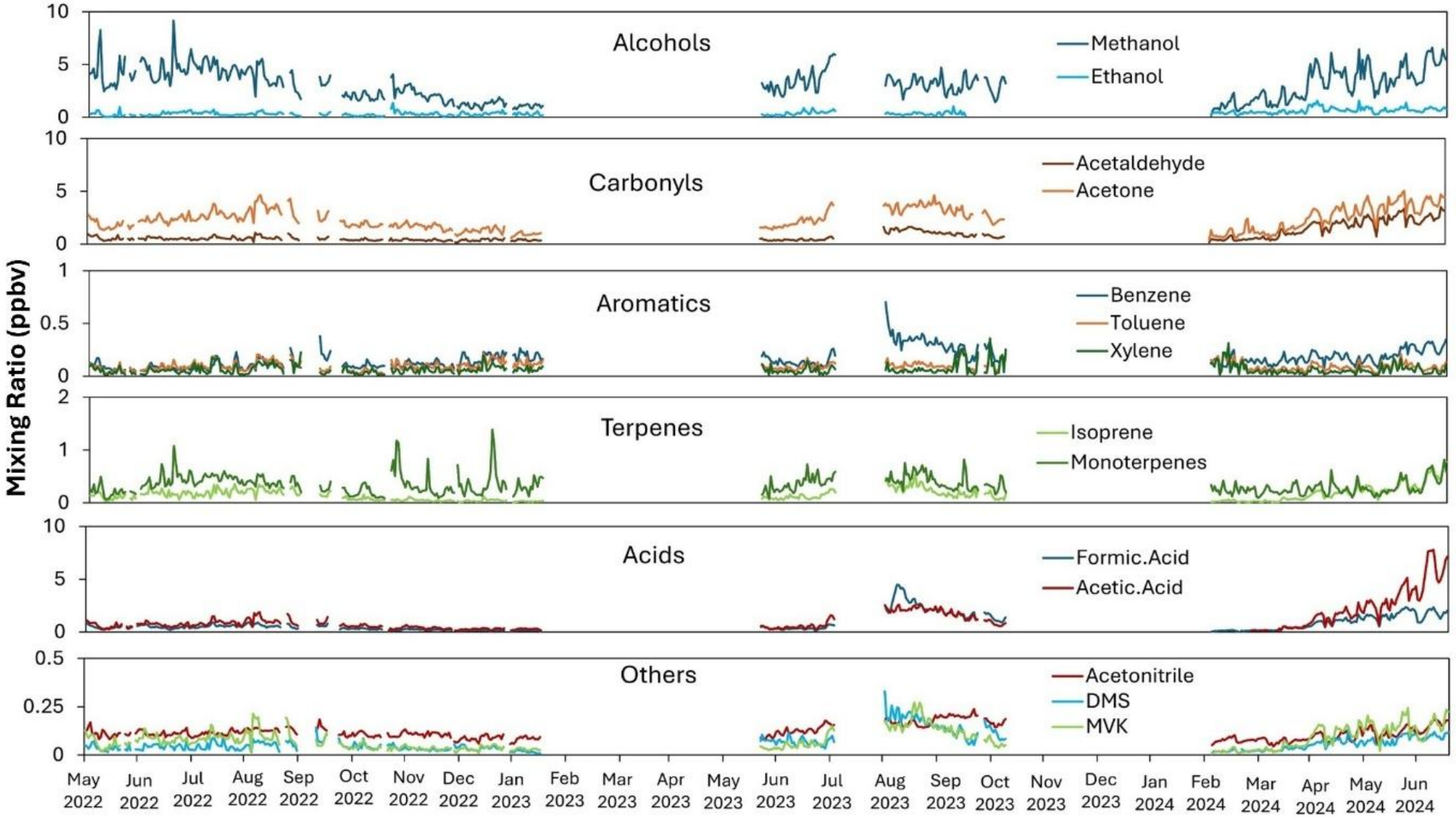

Figure S2: Time Series of selected VOC Mixing Ratios (ppbv) at CAO-AMX from 2022 to 2024. The VOCs are categorized into six groups: alcohols (methanol, ethanol), carbonyls (acetaldehyde, acetone), aromatics (benzene, toluene, xylene), terpenes (isoprene, monoterpenes), acids (formic acid, acetic acid), and others (acetonitrile, DMS, MVK). The data highlight seasonal and interannual variability, with notably higher levels of alcohols and carbonyls compared to aromatics, terpenes, and other VOCs.

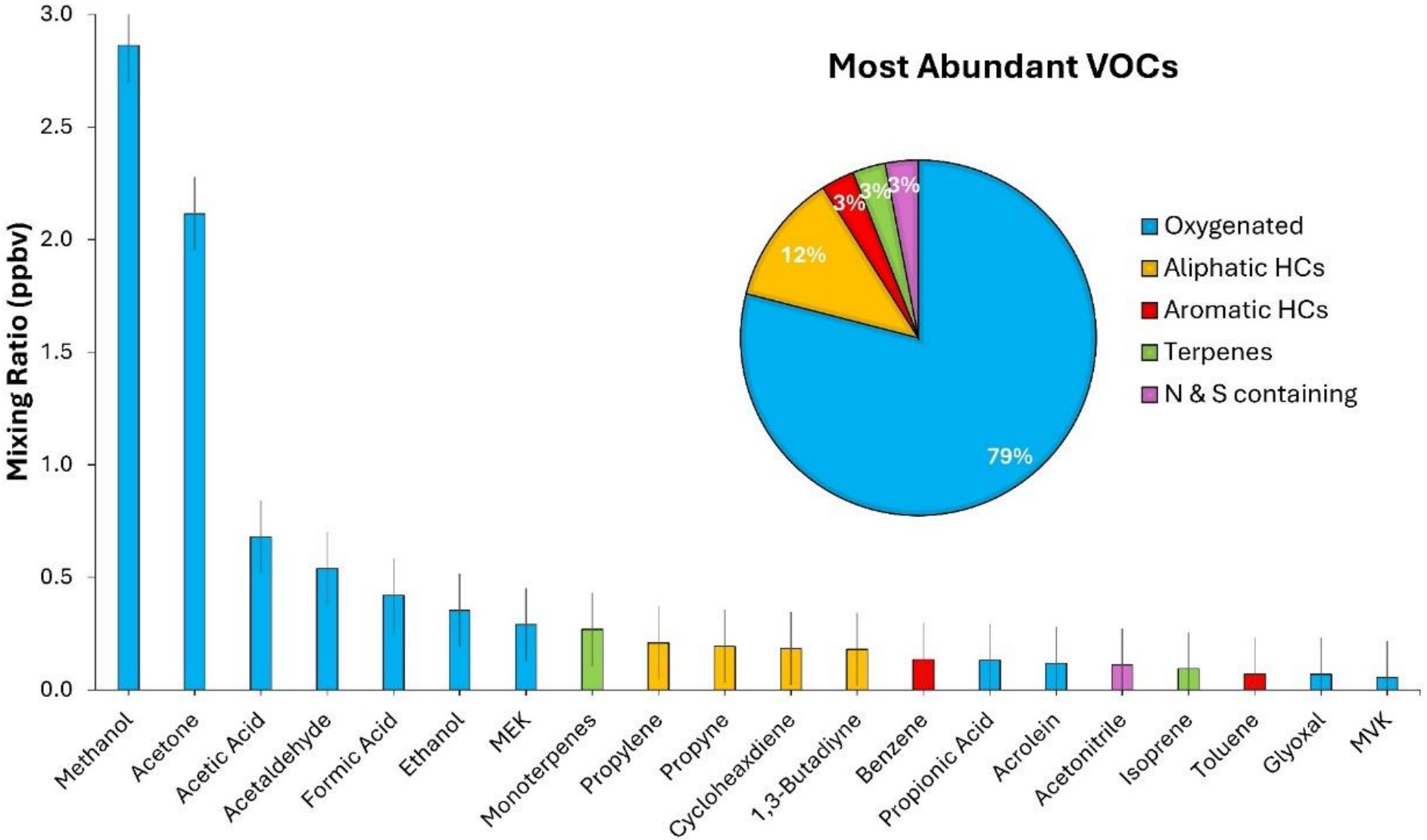

Figure S3: Top 20 most abundant VOCs observed during entire study period. Bar chart showing the average mixing ratios (ppbv) of the most abundant VOCs measured, with error bars representing standard deviations. The pie chart presents the contribution of chemical classes to total measured VOCs, highlighting the predominance of oxygenated VOCs (OVOCs, 79%)

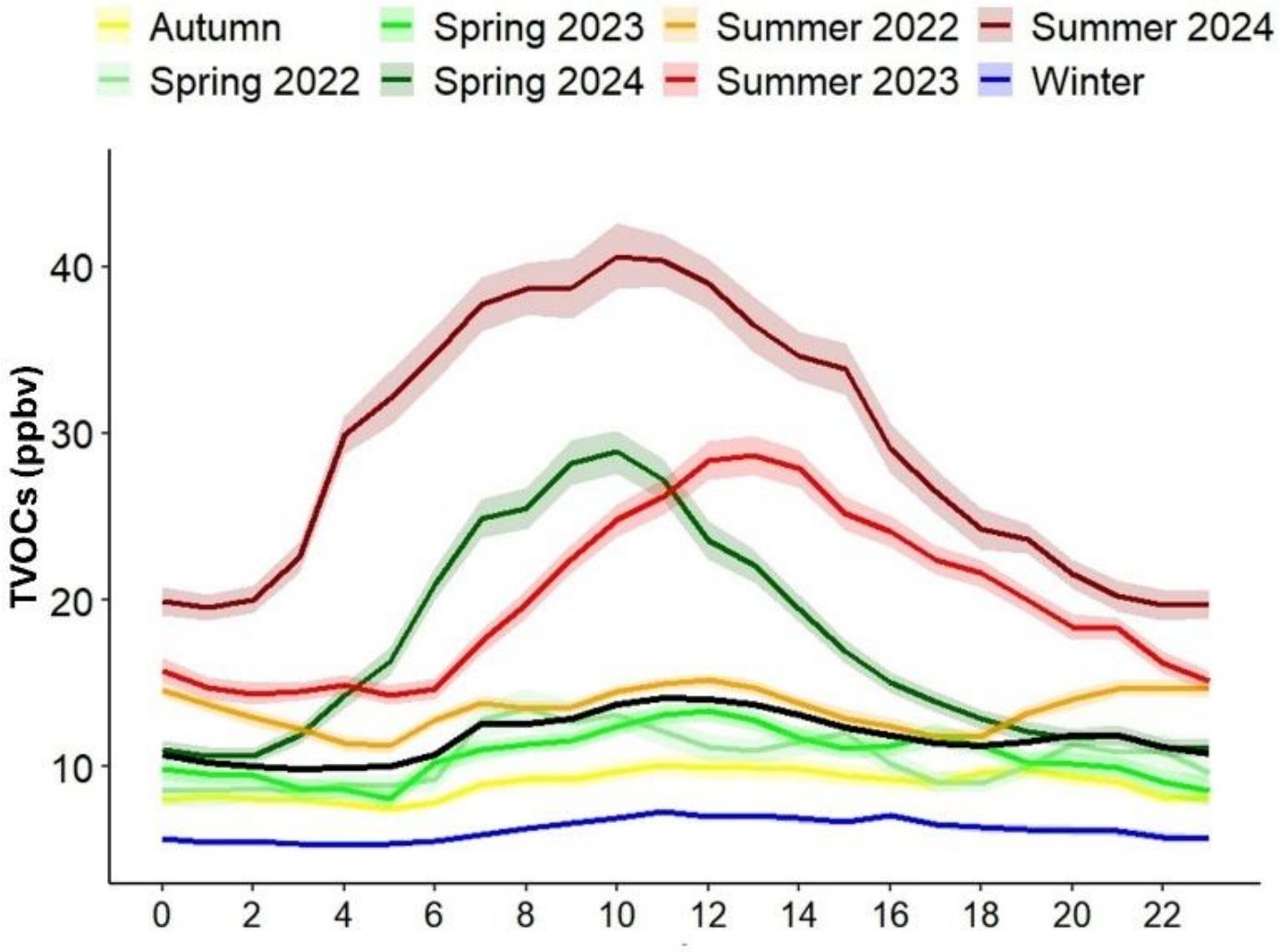

Figure S4: Diurnal variation of total VOCs (TVOCs) across seasons and years. The mixing ratios (in ppbv) are hourly averaged for different seasons and years observed. Seasonal curves are color-coded by year and season. Shaded areas around each line represent the standard error. The black line represents the overall average across all periods.

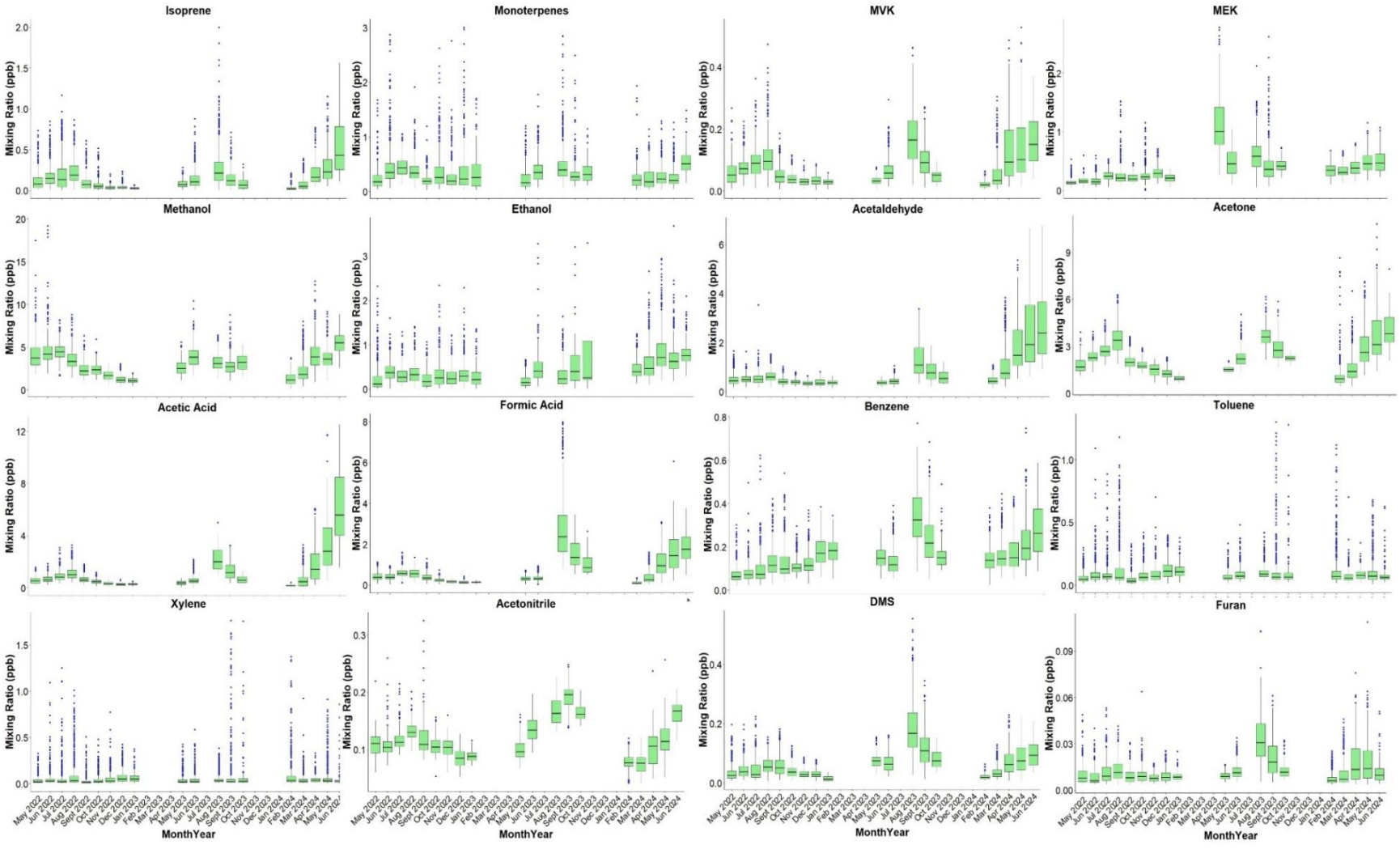

Figure S5: Monthly variation in the mixing ratio of selected VOCs.

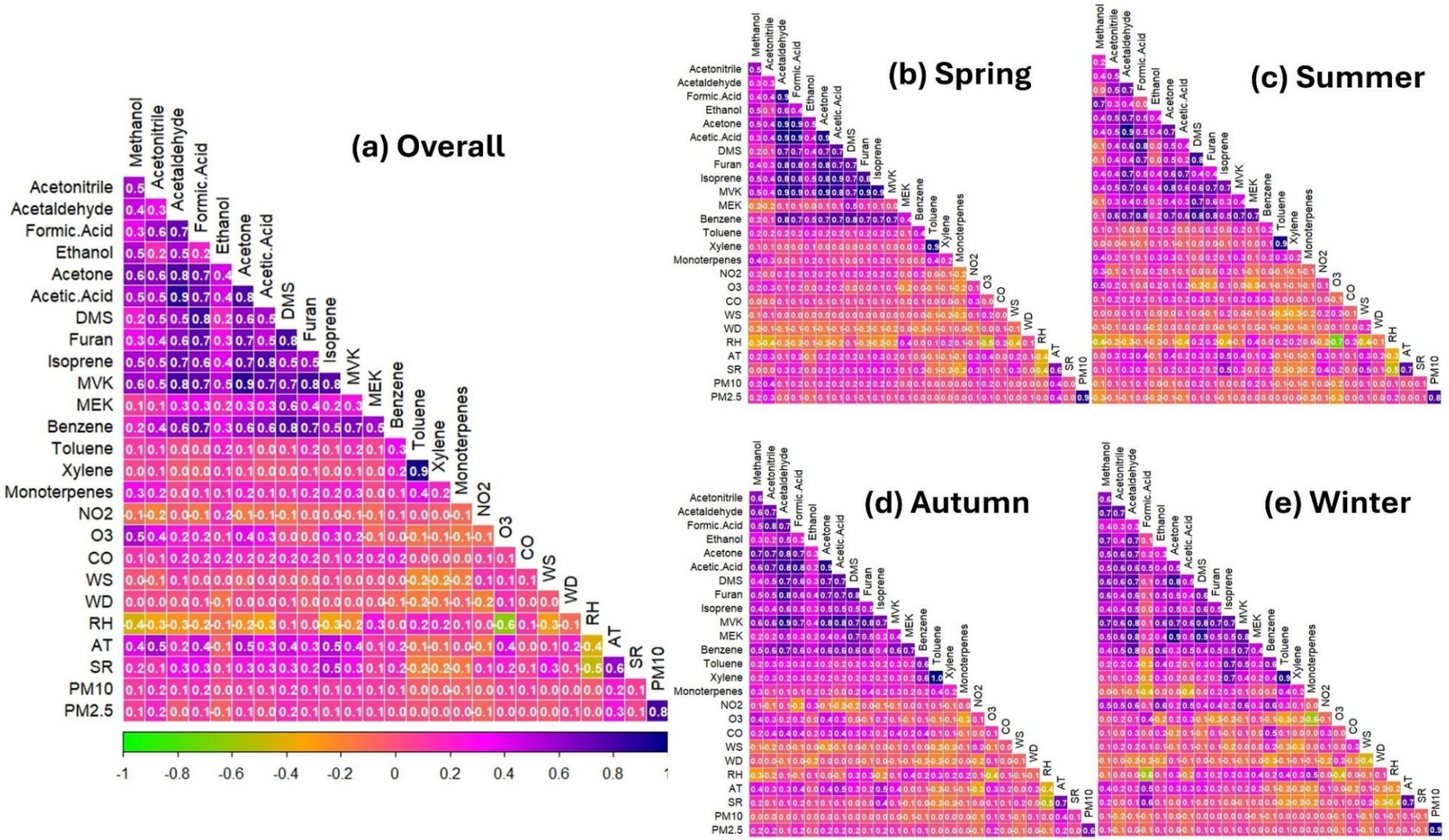

Figure S6: **Correlation matrices of VOCs, trace gases, meteorological parameters, and particulate matter.** Pearson correlation matrices for (a) the overall dataset and individual seasons—(b) spring, (c) summer, (d) autumn, and (e) winter—showing relationships between various volatile organic compounds (VOCs), trace gases (e.g., NO_2, O_3, CO), meteorological variables (e.g., wind speed (WS), wind direction (WD), relative humidity (RH), air temperature (AT), solar radiation (SR)), and particulate matter (PM_{10} and $PM_{2.5}$).

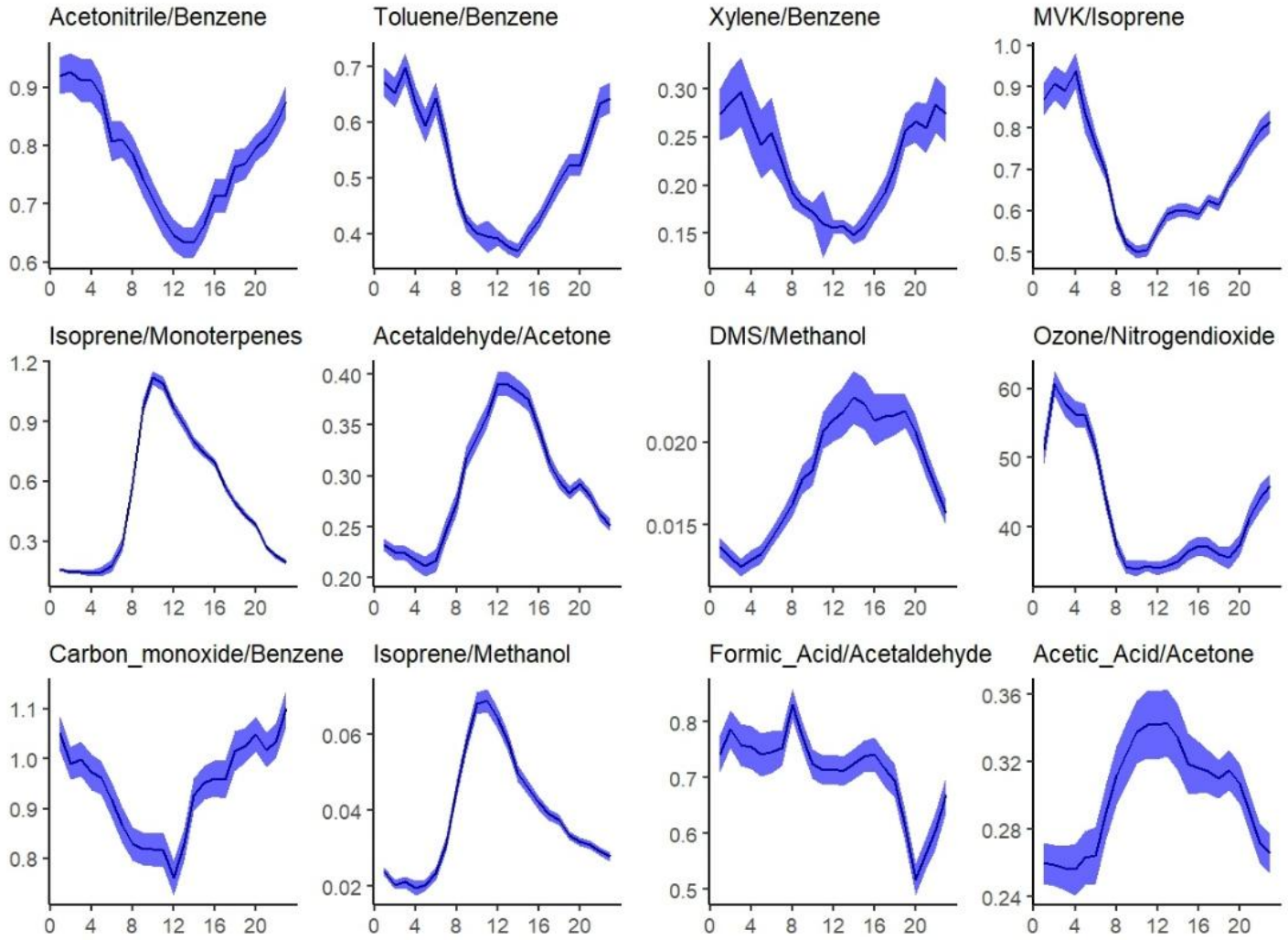

Figure S7: Diurnal variation of selected VOC and trace gas ratios as indicators of sources and photochemical processing. Shaded regions represent the standard error, capturing the variability in measurements.

Clusters	C0	C1	C2	C3	C4	C5	C6
Cluster Name	Slow Moving	North Africa	Marine	Europe	Northwest Asia	West Turkey	Middle East
Spring	1.7%	9.7%	12.3%	40.2%	28.7%	4.1%	3.3%
Summer	0.6%	3.8%	7.7%	35.5%	47.6%	4.6%	0.2%
Autumn	2.8%	9.2%	17%	25.6%	35.8%	5.5%	4.1%
Winter	1.8%	9.8%	18.2%	32.1%	24.2%	3.2%	10.7%

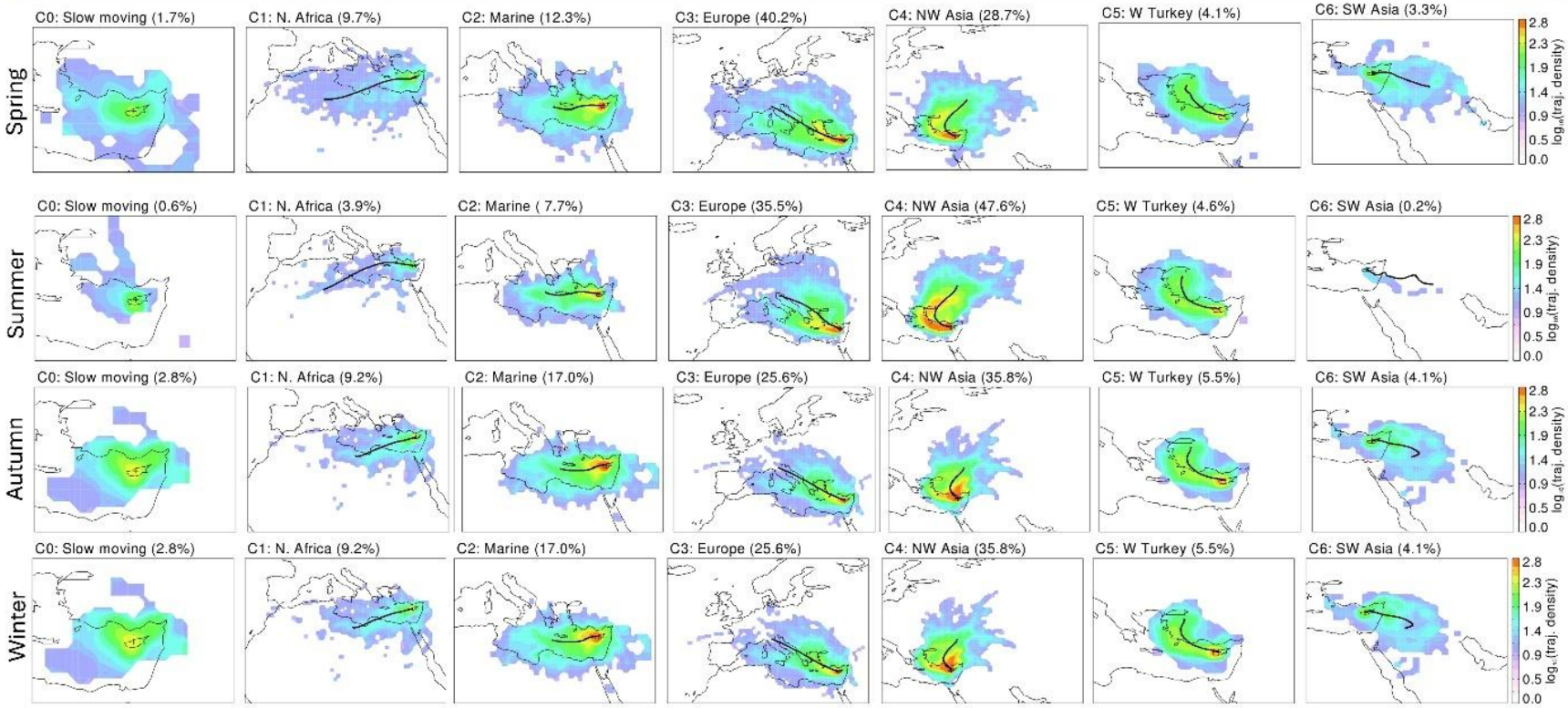

Figure S8: Seasonal distribution of air mass back-trajectory clusters (2022–2024). This figure represents seasonal cluster analysis of 5-day air mass back-trajectories arriving at the Cyprus regional background monitoring station for the years 2022–2024, using the HYSPLIT model. Seven major clusters (C0–C6) were identified, representing distinct geographical source regions: C0 (Slow Moving), C1 (North Africa), C2 (Marine), C3 (Europe), C4 (Northwest Asia), C5 (West Turkey), and C6 (Southwest Asia). The top panel summarizes the seasonal frequency (%) of each cluster, while the subsequent panels display the spatial density of trajectories for each season. Color scale indicates trajectory density in $\log_{10}$ scale, highlighting dominant transport pathways.

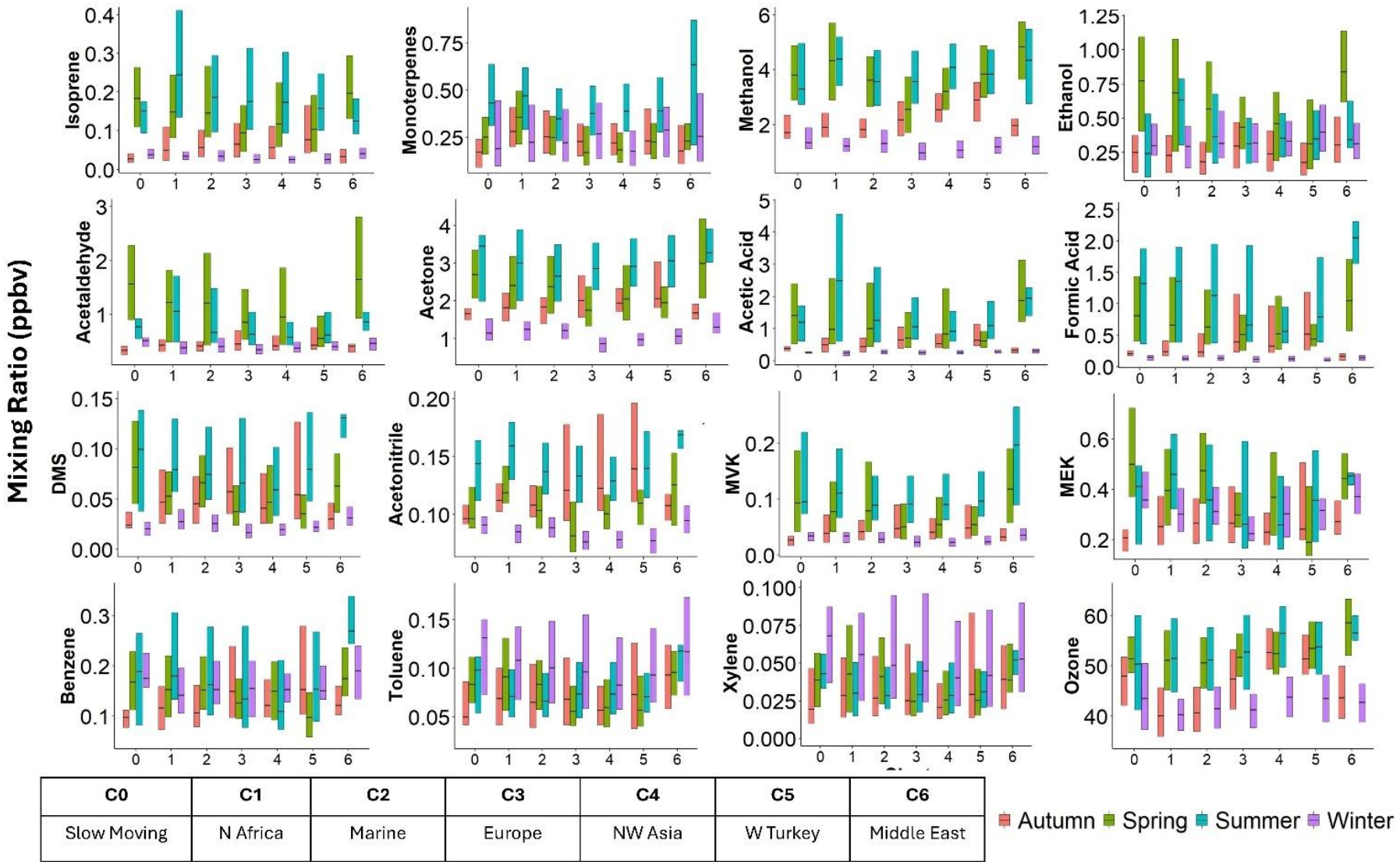

Figure S9: Seasonal mixing ratios of VOCs, and selected air pollutants across air mass clusters. Boxplots showing the distribution of mixing ratios of selected VOCs, and other air pollutants for different air mass clusters (C0–C6) identified by back trajectory analysis. Clusters represent different air mass origins: C0 – Slow Moving, C1 – North Africa, C2 – Marine, C3 – Europe, C4 – Northwest Asia, C5 – Western Turkey, and C6 – Southwest Asia. The black line within each box represents the median, boxes indicate the interquartile range, and whiskers denote variability outside the upper and lower quartiles.

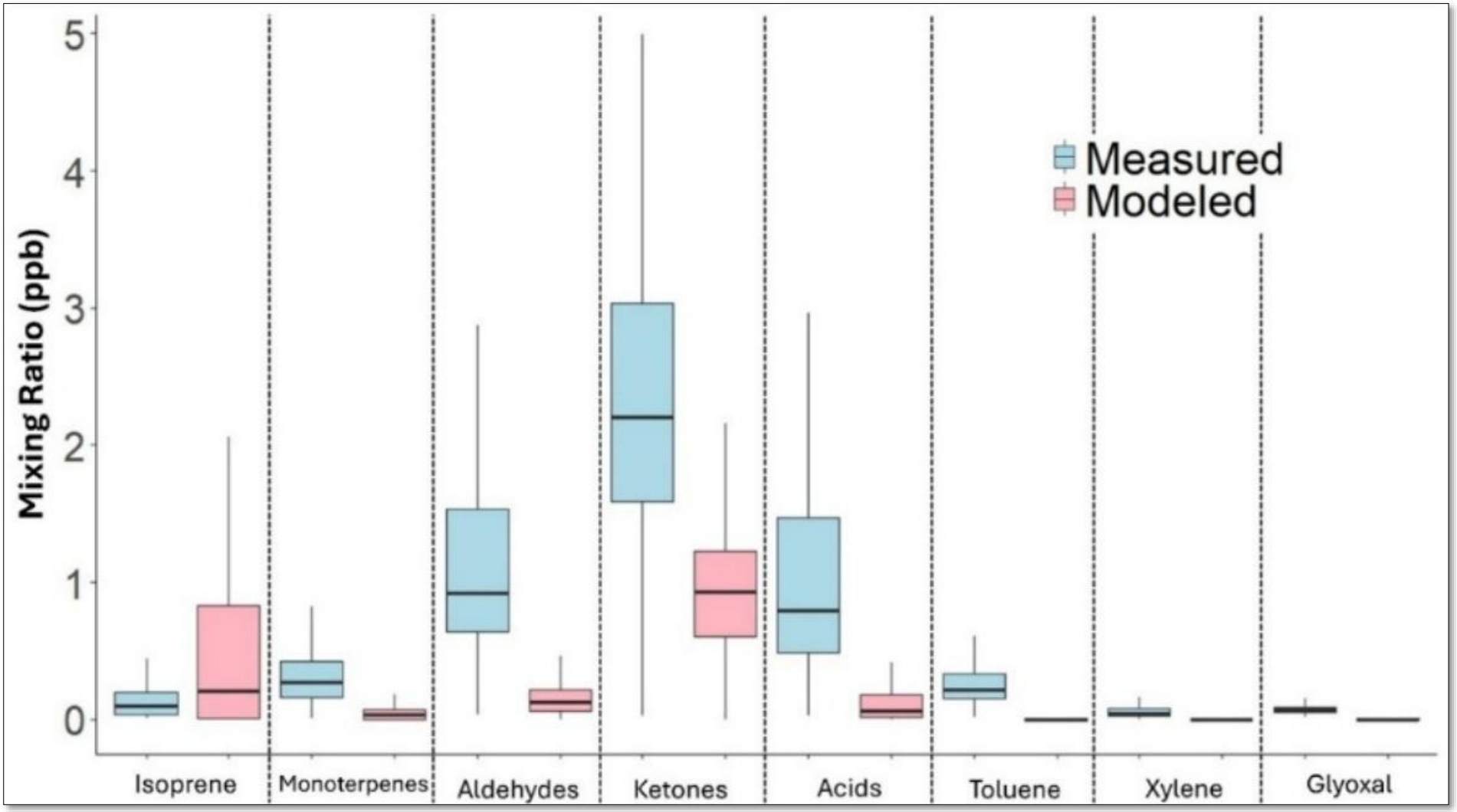

Figure S10: Comparison of measured and modeled volatile organic compound (VOC) mixing ratios in Cyprus.

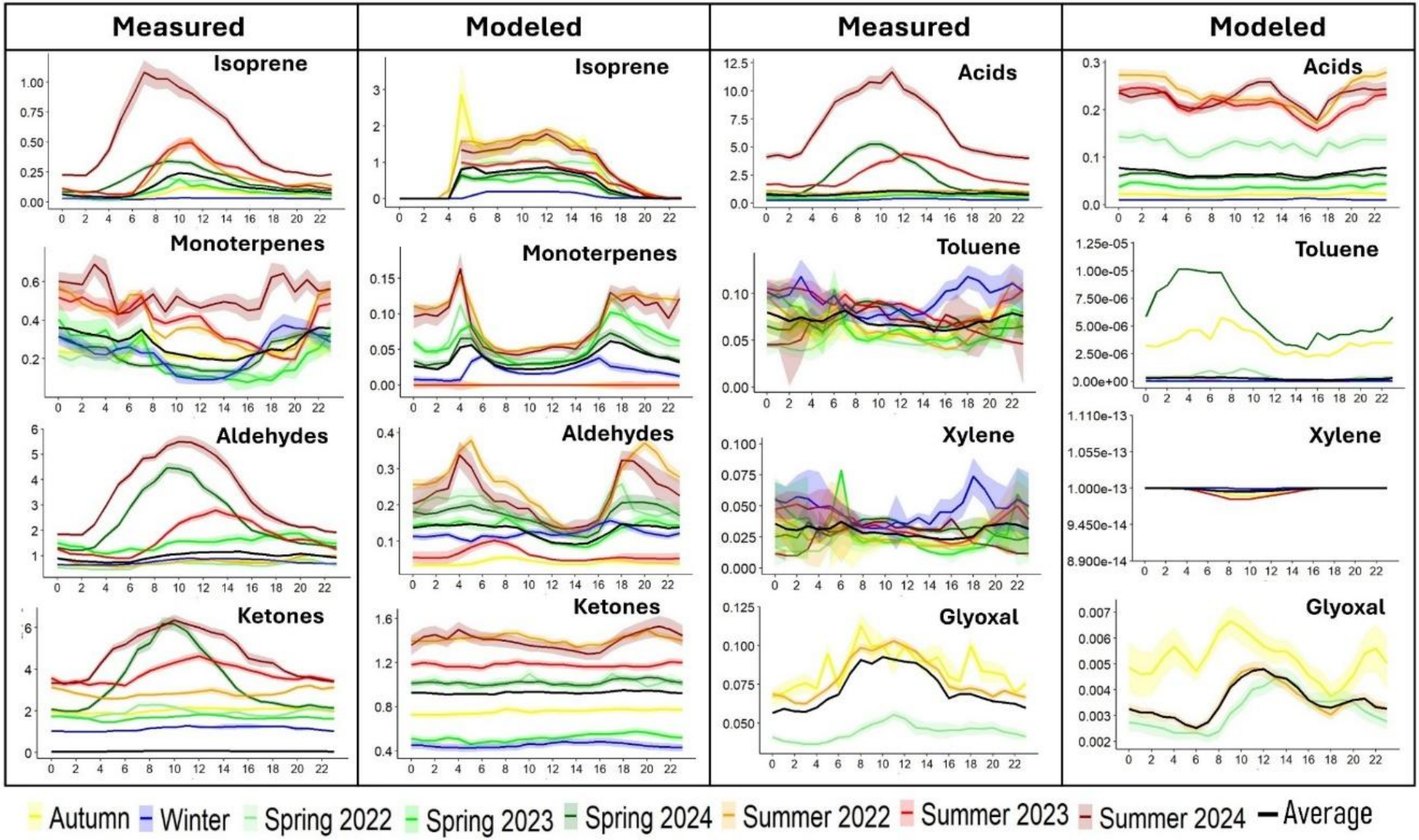

Figure S11: Diurnal and seasonal variability among measured and simulated VOCs mixing ratios (in ppbv).