



Supplement of

Heat and continental transport shape the variability of volatile organic compounds in the Eastern Mediterranean: insights from multi-year observations and regional modeling

Anchal Garg et al.

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Supplimentary Material

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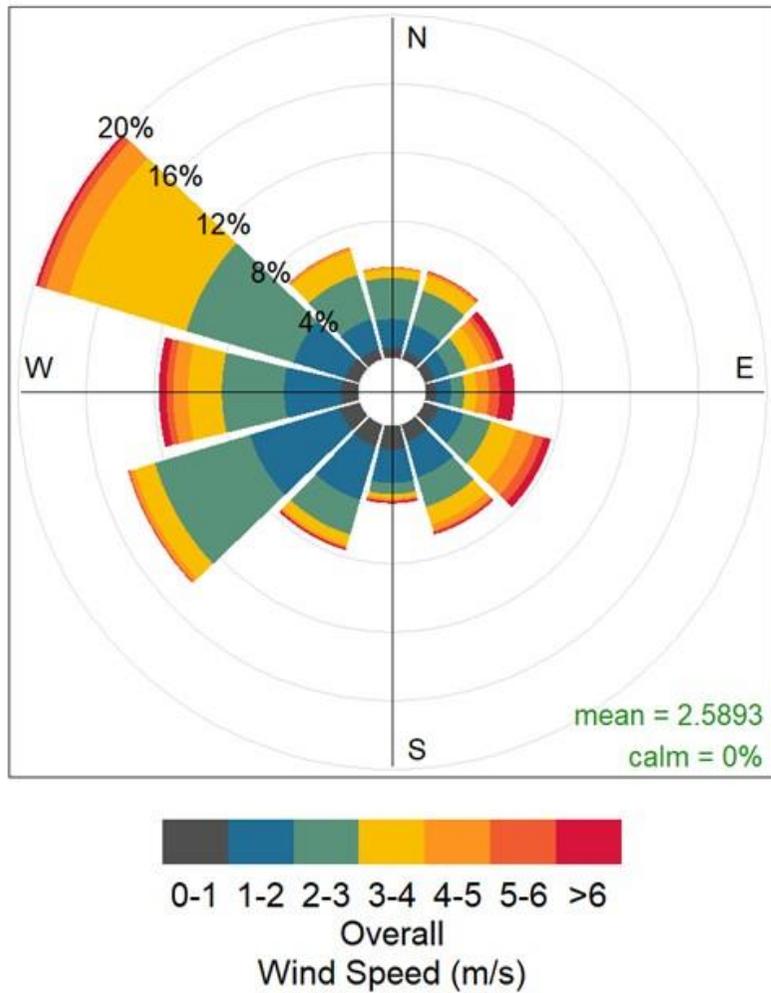
Table S1: Descriptive statistics of VOCs (in ppbv) measured at rural background site in Cyprus from 2022-2024

Species	Species Name	Protonated Molar Mass	Group	Mean	Median	SD	SE	LB	UB	95 th Percentile	Minimum	Maximum
CH ₄ O	Methanol	33.033	Alcohol	3.08	2.861	1.707	0.017	3.046	3.114	5.994	0.138	27.824
C ₃ H ₄	Propyne	41.039	Aliphatic	0.257	0.194	0.213	0.002	0.253	0.261	0.649	0.022	4.612
C ₂ H ₃ N	Acetonitrile	42.039	N	0.117	0.111	0.038	0	0.116	0.118	0.194	0.041	0.325
C ₃ H ₆	Propylene	43.054	Aliphatic	0.257	0.208	0.185	0.002	0.253	0.261	0.626	0.019	2.073
C ₂ H ₄ O	Acetaldehyde	45.033	Carbonyls	0.883	0.54	0.888	0.009	0.866	0.9	2.964	0.123	6.756
CH ₃ NO	Formamide	46.029	N	0.063	0.042	0.052	0.001	0.062	0.064	0.186	0.017	0.353
CH ₂ O 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 ₂ H ₆ O	Ethanol	47.049	Alcohol	0.433	0.353	0.349	0.004	0.425	0.44	1.074	0.009	3.683
C ₄ H 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 ₂ H ₃ NO	Hydroxyacetonitrile	58.029	N	0.009	0.008	0.006	0	0.009	0.009	0.021	0.003	0.046
C ₃ H ₆ O	Acetone	59.049	Carbonyls	2.348	2.115	1.186	0.012	2.325	2.371	4.547	0.429	10.818
C ₂ H ₄ O 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 ₂ H ₆ S	Dimethyl Sulfide	63.044	S	0.064	0.044	0.059	0.001	0.063	0.065	0.181	0.005	0.554
C ₅ H ₆	Cyclopentadiene	67.054	Aliphatic	0.012	0.01	0.007	0	0.012	0.012	0.026	0.003	0.081
C ₄ H ₄ O	Furan	69.033	Oxygenated	0.014	0.01	0.011	0	0.013	0.014	0.038	0.004	0.159
C ₅ H ₈	Isoprene	69.07	Terpenes	0.155	0.094	0.183	0.002	0.151	0.158	0.521	0.005	2
C ₄ H ₆ O	MVK/Methacrolein	71.049	Oxygenated	0.08	0.056	0.072	0.001	0.079	0.082	0.24	0.003	0.529
C ₂ H ₅ N ₃	Ethyl azide	72.056	N	0.008	0.006	0.006	0	0.008	0.008	0.02	0.002	0.048
C ₄ H ₈ O	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 ₂ H ₃ NO ₂	Nitroethylene	74.024	N	0.007	0.006	0.004	0	0.007	0.007	0.015	0.002	0.03
C ₃ H ₆ O ₂	Propionic Acid	75.044	Acids	0.21	0.131	0.222	0.002	0.206	0.215	0.712	0.01	1.545

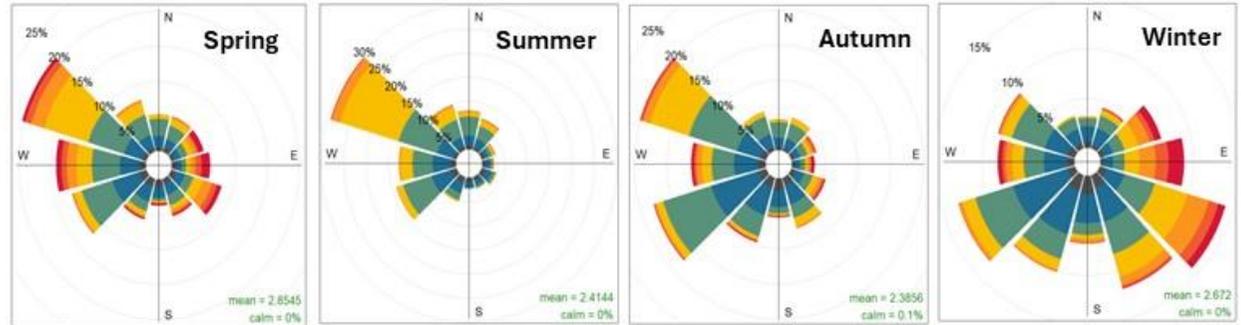
C ₂ H ₄ O ₃	Peracetic Acid	77.023	Acids	0.046	0.038	0.032	0	0.045	0.047	0.116	0.004	0.24
C ₃ H ₈ O ₂	Propylene glycol	77.06	Alcohol	0.073	0.051	0.058	0.001	0.071	0.074	0.185	0.005	0.463
C ₆ H ₆	Benzene	79.054	Aromatics	0.165	0.135	0.106	0.001	0.163	0.167	0.386	0.018	1.087
C ₅ H ₅ N	Pyridine	80.049	N	0.008	0.008	0.004	0	0.008	0.008	0.016	0.002	0.036
C ₆ H ₈	Cyclohexadiene	81.071	Aliphatic	0.23	0.184	0.184	0.002	0.226	0.234	0.546	0.016	2.101
C ₆ H ₉	Cyclopentenyl Carbenium	82.078	Aromatics	0.016	0.013	0.012	0	0.016	0.016	0.038	0.002	0.139
C ₄ H ₄ O 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 ₅ H ₈ O	Cyclopentanone	85.065	Carbonyls	0.029	0.017	0.034	0	0.029	0.03	0.099	0.002	0.296
C ₄ H ₇ NO	Methacrylamide	86.06	N	0.004	0.003	0.004	0	0.004	0.004	0.012	0.001	0.035
C ₄ H ₆ O 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 ₅ H 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 ₃ H ₄ O ₃	Pyruvic Acid	89.023	Acids	0.009	0.006	0.008	0	0.009	0.009	0.023	0.002	0.077
C ₄ H ₈ O ₂	Methyl Carbonate	89.06	Oxygenated	0.04	0.029	0.034	0	0.039	0.041	0.114	0.003	0.264
C ₇ H ₈	Toluene	93.07	Aromatics	0.096	0.07	0.098	0.001	0.094	0.098	0.243	0.005	1.302
C ₆ H ₆ O	Phenol	95.049	Aromatics	0.018	0.01	0.027	0	0.018	0.019	0.055	0.005	0.491
C ₇ H 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 ₅ H ₄ O ₂	Furfural	97.028	Carbonyls	0.021	0.007	0.036	0	0.02	0.022	0.092	0.002	0.394
C ₄ H ₂ O ₃	Maleic anhydride	99.008	Oxygenated	0.016	0.012	0.017	0	0.016	0.017	0.044	0.003	0.221
C ₄ H ₄ O ₃	Succinic anhydride	101.023	Oxygenated	0.019	0.011	0.019	0	0.018	0.019	0.06	0.003	0.276
C ₅ H ₈ O ₂	Acetylacetone	101.06	Carbonyls	0.104	0.043	0.17	0.002	0.1	0.107	0.459	0.004	1.363
C ₆ H ₁₂ O	Hexanal	101.096	Carbonyls	0.017	0.01	0.02	0	0.016	0.017	0.059	0.002	0.145
C ₄ H ₆ O ₃	Propylene Carbonate	103.039	Oxygenated	0.014	0.008	0.015	0	0.014	0.014	0.048	0.002	0.098
C ₇ H ₅ N	Benzonitrile	104.049	N	0.004	0.004	0.003	0	0.004	0.004	0.008	0.001	0.064
C ₇ H ₄ O	Ethynyl cyclopentadienone	105.033	Carbonyls	0.006	0.004	0.005	0	0.006	0.006	0.018	0.002	0.041

C ₈ H ₈	Styrene	105.07	Aromatics	0.019	0.015	0.014	0	0.018	0.019	0.043	0.002	0.142
C ₃ H ₆ O ₄	Glyceric acid	107.03		0.014	0.009	0.018	0	0.014	0.015	0.042	0.002	0.217
C ₈ H ₁₀	Xylene	107.086	Aromatics	0.062	0.029	0.119	0.001	0.06	0.065	0.229	0.003	1.764
C ₇ H ₉ N	Dimethyl+Ethyl Pyridine	108.081	N	0.006	0.004	0.008	0	0.006	0.007	0.018	0.001	0.125
C ₇ H 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 ₅ H ₇ NO ₂	Ethyl cyanoacetate	114.055	N	0.006	0.004	0.005	0	0.006	0.006	0.016	0.002	0.038
C ₆ H 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 ₄ H ₄ O ₄	Maleic Acid	117.018	Acids	0.01	0.005	0.016	0	0.01	0.01	0.039	0.002	0.22
C ₅ H ₈ O ₃	Methyl acetoacetate	117.055	Oxygenated	0.009	0.004	0.013	0	0.009	0.01	0.036	0.002	0.148
C ₄ H ₆ O ₄	Butanedioic acid	119.034	Acids	0.014	0.008	0.016	0	0.014	0.014	0.047	0.002	0.142
C ₆ H 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 ₉ H ₁₂	Trimethylbenzene	121.101	Aromatics	0.045	0.017	0.096	0.001	0.043	0.047	0.189	0.002	1.316
C ₉ H ₁₄	Santene	123.117	Aliphatic	0.008	0.005	0.01	0	0.008	0.009	0.025	0.002	0.111
C ₇ H 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 ₇ H 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 ₆ H 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 ₉ H ₁₃ N	Amphetamine	136.112	N	0.004	0.002	0.003	0	0.003	0.004	0.01	0.001	0.05
C ₅ H ₄ N ₄ O	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 ₉ H ₁₅ N	Triallylamine	138.128	N	0.014	0.011	0.011	0	0.013	0.014	0.033	0.001	0.11
C ₉ H ₁₄ O	Isophorone	139.112	Carbonyls	0.031	0.023	0.026	0	0.031	0.032	0.082	0.002	0.341

C ₇ H 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 ₈ H 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 ₇ H ₆ O ₂	Benzoic acid	123.044	Acids	0.011	0.006	0.011	0	0.01	0.011	0.035	0.003	0.088
C ₃ H ₄ O	Acrolein	57.033	Oxygenated	0.203	0.118	0.229	0.002	0.198	0.207	0.715	0.01	1.933
C ₂ H ₂ O ₂	Glyoxal	59.013	Oxygenated	0.074	0.07	0.042	0.001	0.073	0.076	0.126	0.019	1.22
CH ₄ SO ₃	Methansulfonic acid	96.995	S	0.009	0.008	0.003	0	0.009	0.009	0.015	0.005	0.042



SEASONAL VARIATION



MONTHLY VARIATION

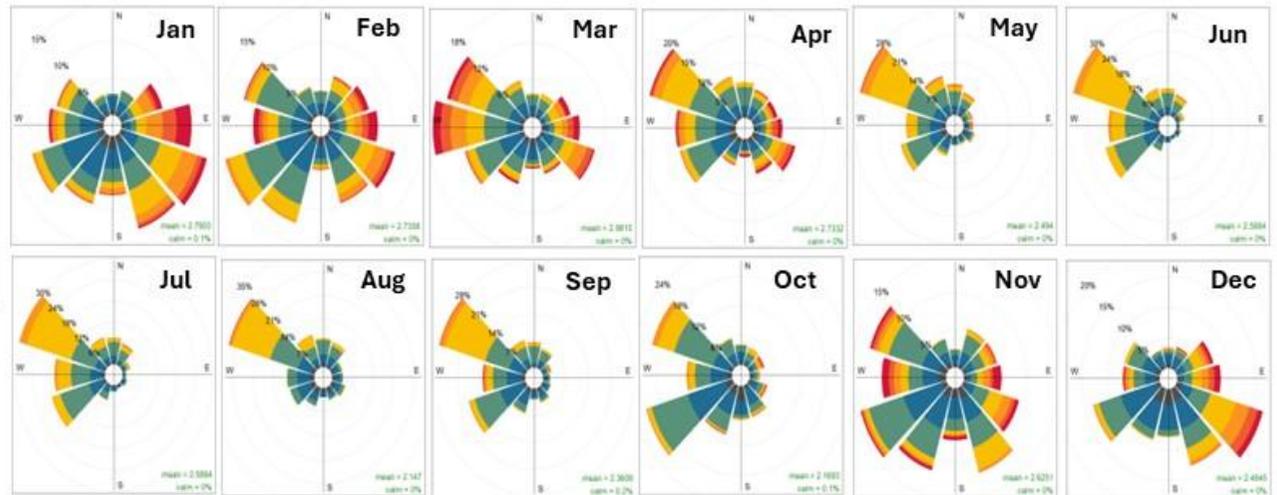


Figure S1: Windrose diagrams showing frequency of counts by wind direction for the period April 2022- June 2024 at the rural background site of Cyprus.

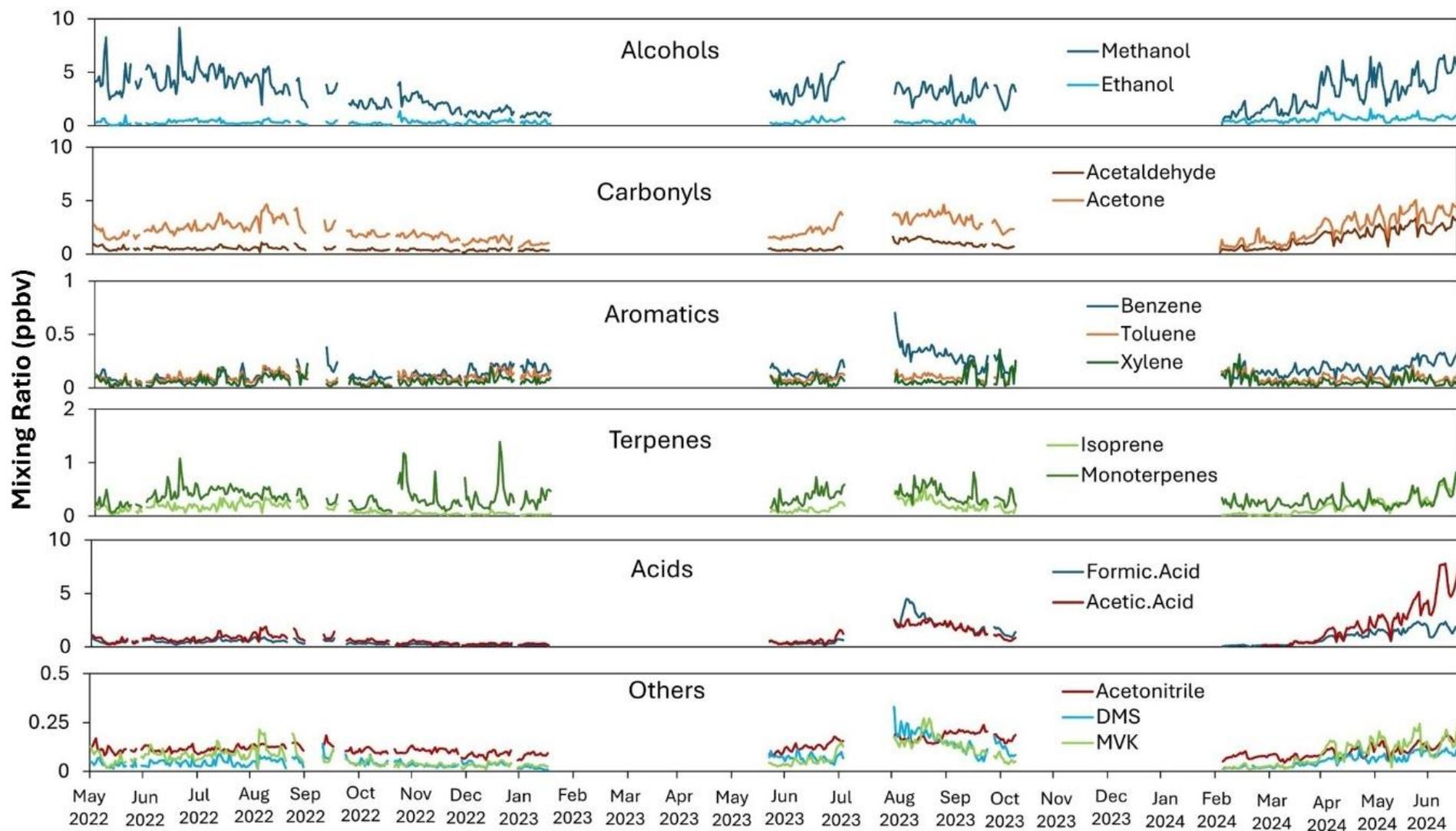


Figure S2: Time Series of selected VOC Mixing Ratios (ppbv) at CAO-AMX from 2022 to 2024. The VOCs are categorized into six groups: alcohols (methanol, ethanol), carbonyls (acetaldehyde, acetone), aromatics (benzene, toluene, xylene), terpenes (isoprene, monoterpenes), acids (formic acid, acetic acid), 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.

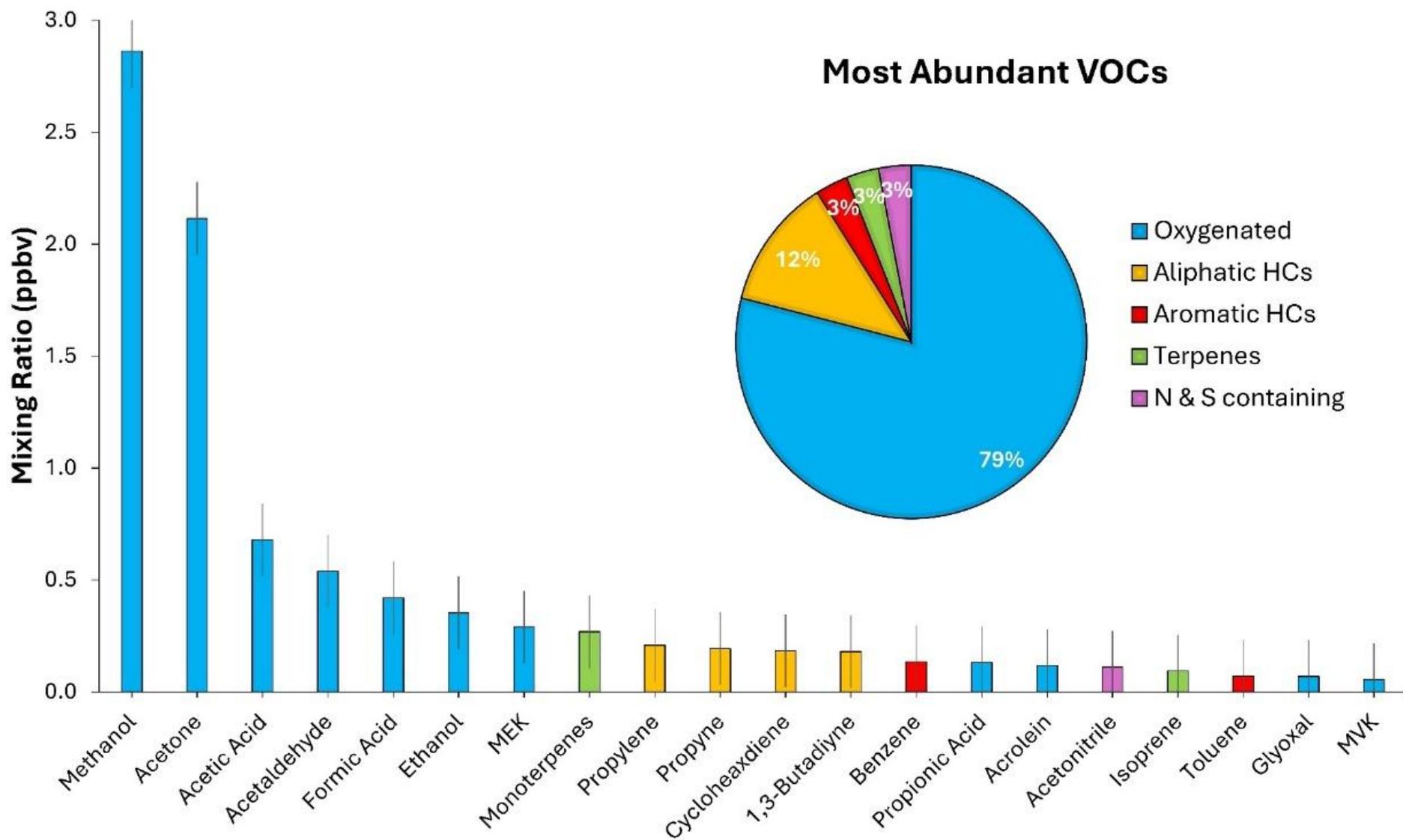


Figure S3: Top 20 most abundant VOCs observed during entire study period. Bar chart showing the average mixing ratios (ppbv) of the most abundant VOCs measured, with error bars representing standard deviations. The pie chart presents the contribution of chemical classes to total measured VOCs, highlighting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

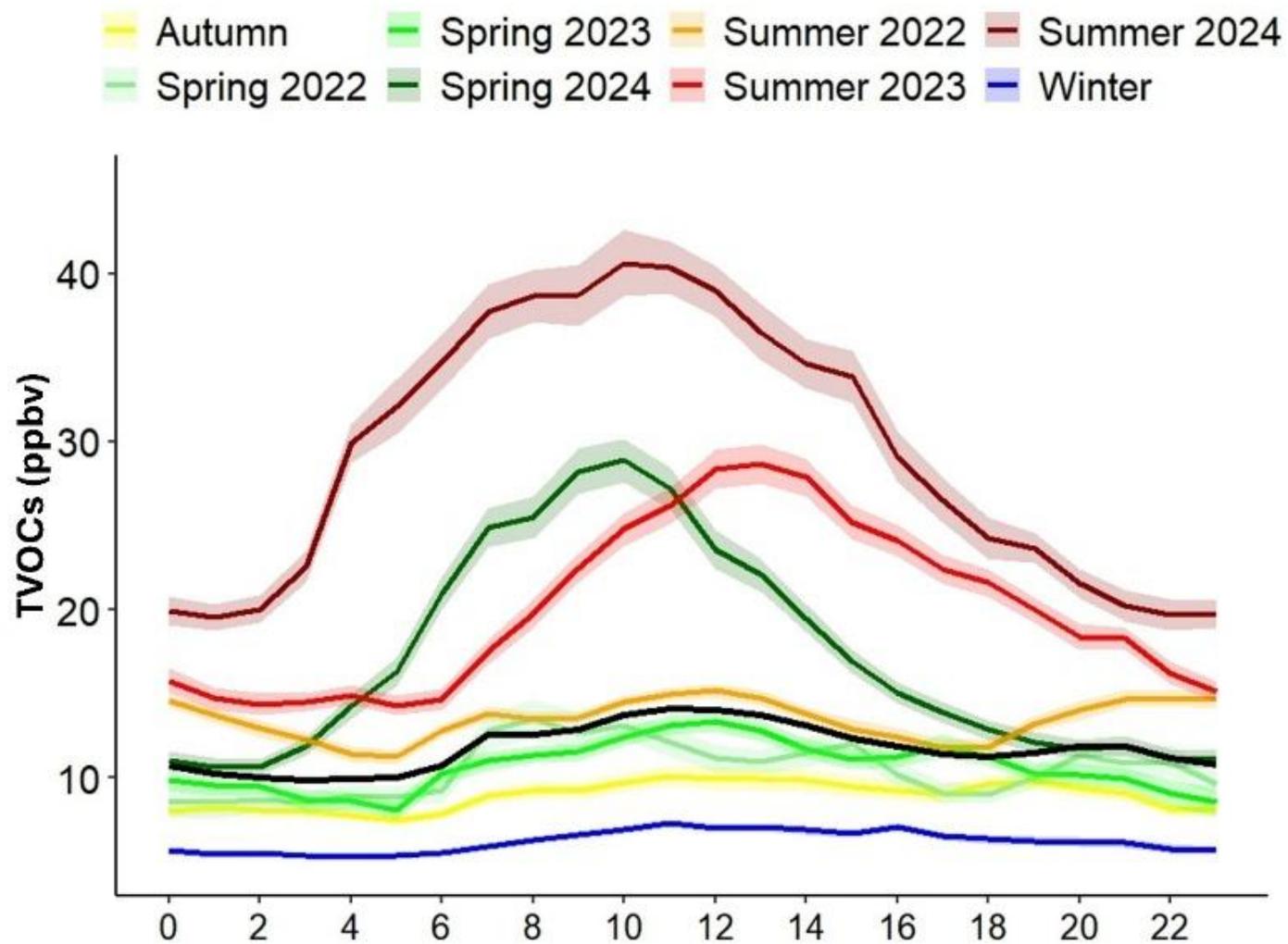


Figure S4: Diurnal variation of total VOCs (TVOCs) across seasons and years. The mixing ratios (in ppbv) are hourly averaged for different seasons and years observed. Seasonal curves are color-coded by year and season. Shaded areas around each line represent the standard error. The black line represents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

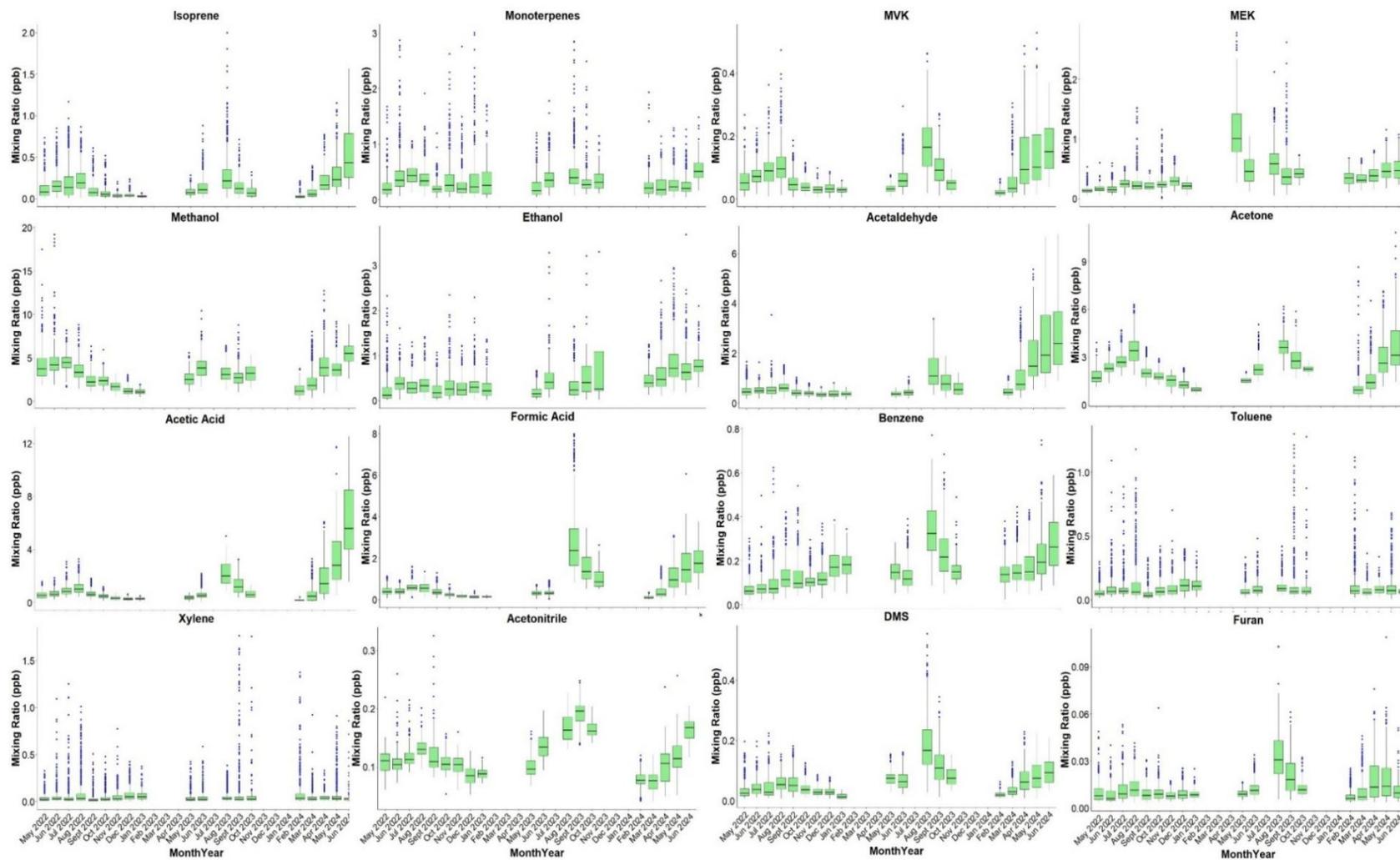


Figure S5: Monthly variation in the mixing ratio of selected VOCs.

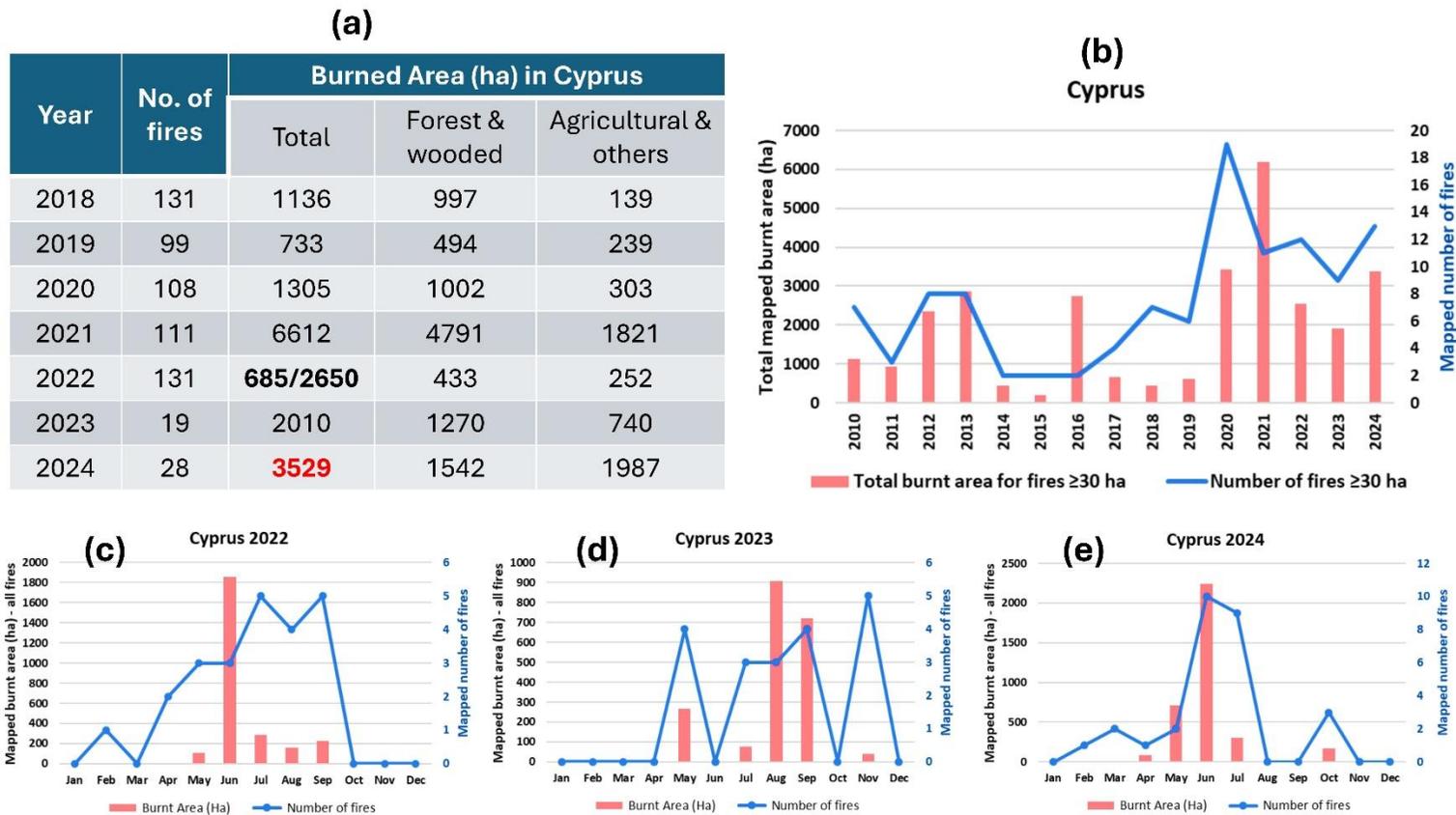


Figure S6. Interannual and seasonal variability of wildfire activity and burned area in Cyprus. (a) Annual statistics of wildfire occurrence and burned area in Cyprus from 2018 to 2024, including total burned area and its partitioning into forested/wooded and agricultural/other land-cover types. (b) Interannual variability (2010-2024) in total burned area and number of large fires (≥ 30 ha). (c-e) Monthly distribution of burned area and number of fires for 2022, 2023, and 2024, respectively.

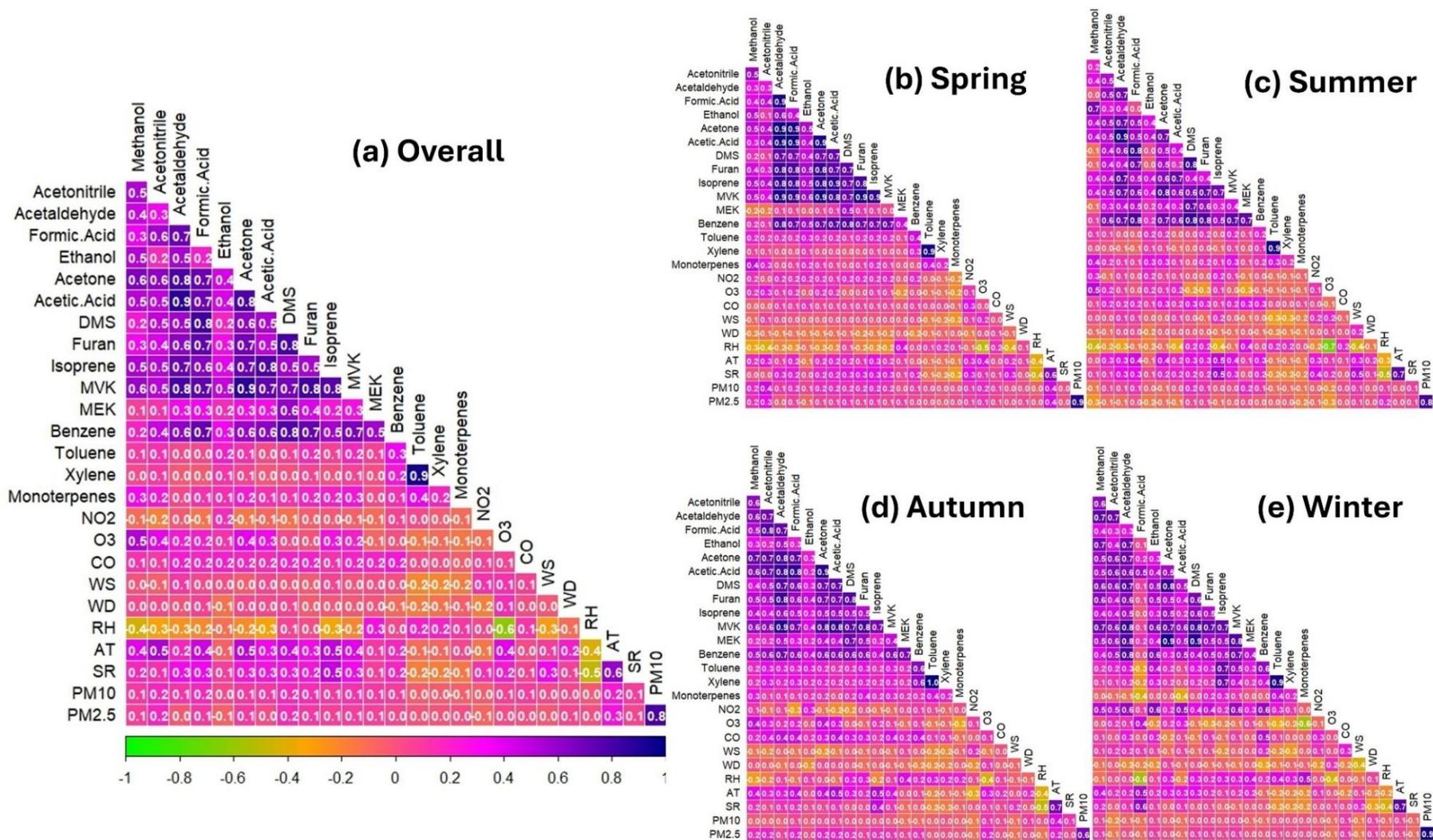


Figure S7: Correlation matrices of VOCs, trace gases, meteorological parameters, and particulate matter. Pearson correlation matrices for (a) the overall dataset and individual seasons—(b) spring, (c) summer, (d) autumn, and (e) winter—showing relationships between various volatile organic compounds (VOCs), trace gases (e.g., NO₂, O₃, CO), meteorological variables (e.g., wind speed (WS), wind direction (WD), relative humidity (RH), air temperature (AT), solar radiation (SR)), and particulate matter (PM₁₀ and PM_{2.5}).

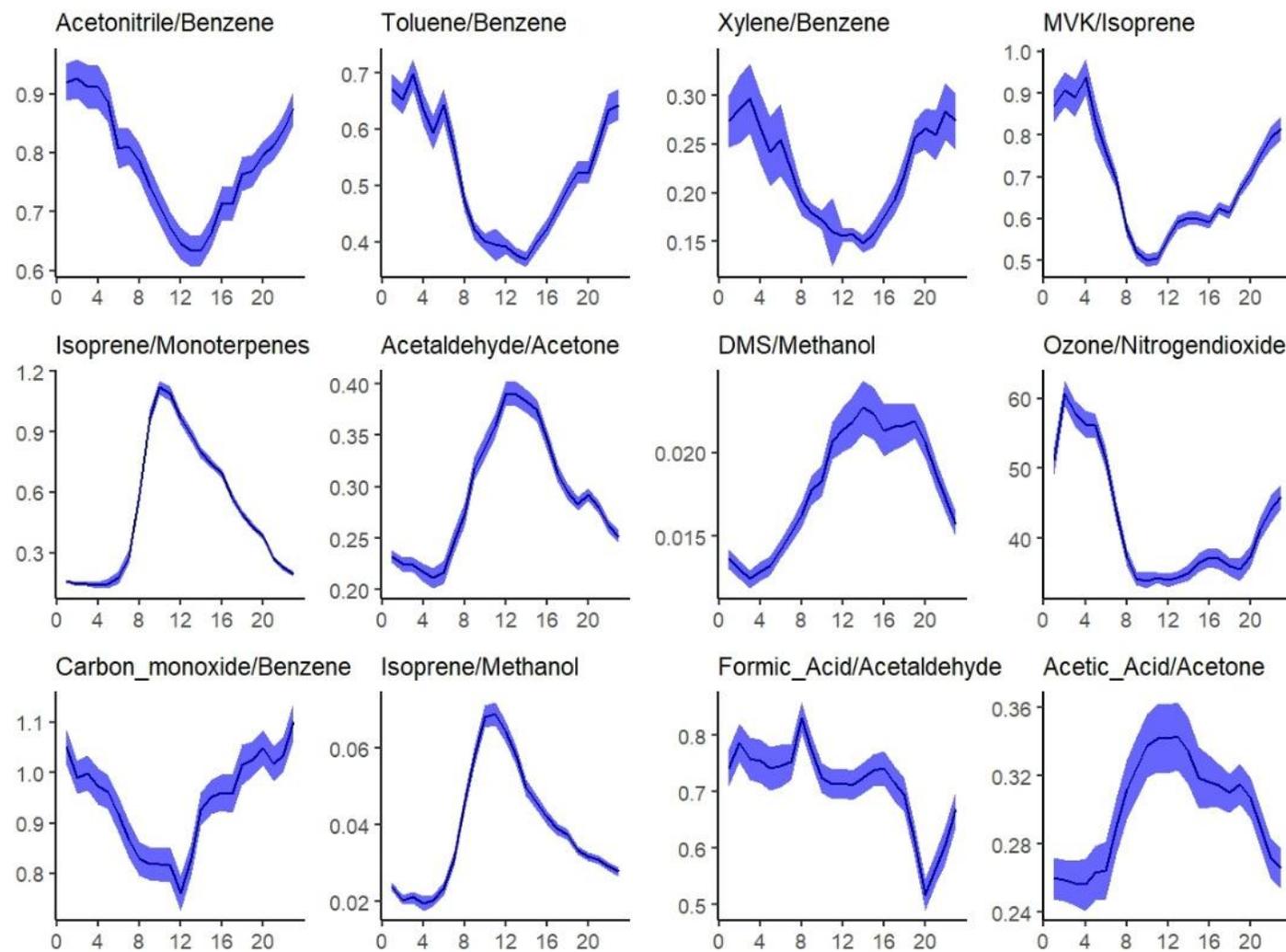


Figure S8: Diurnal variation of selected VOC and trace gas ratios as indicators of sources and photochemical processing. Shaded regions represent the standard error, capturing the variability in measurements.

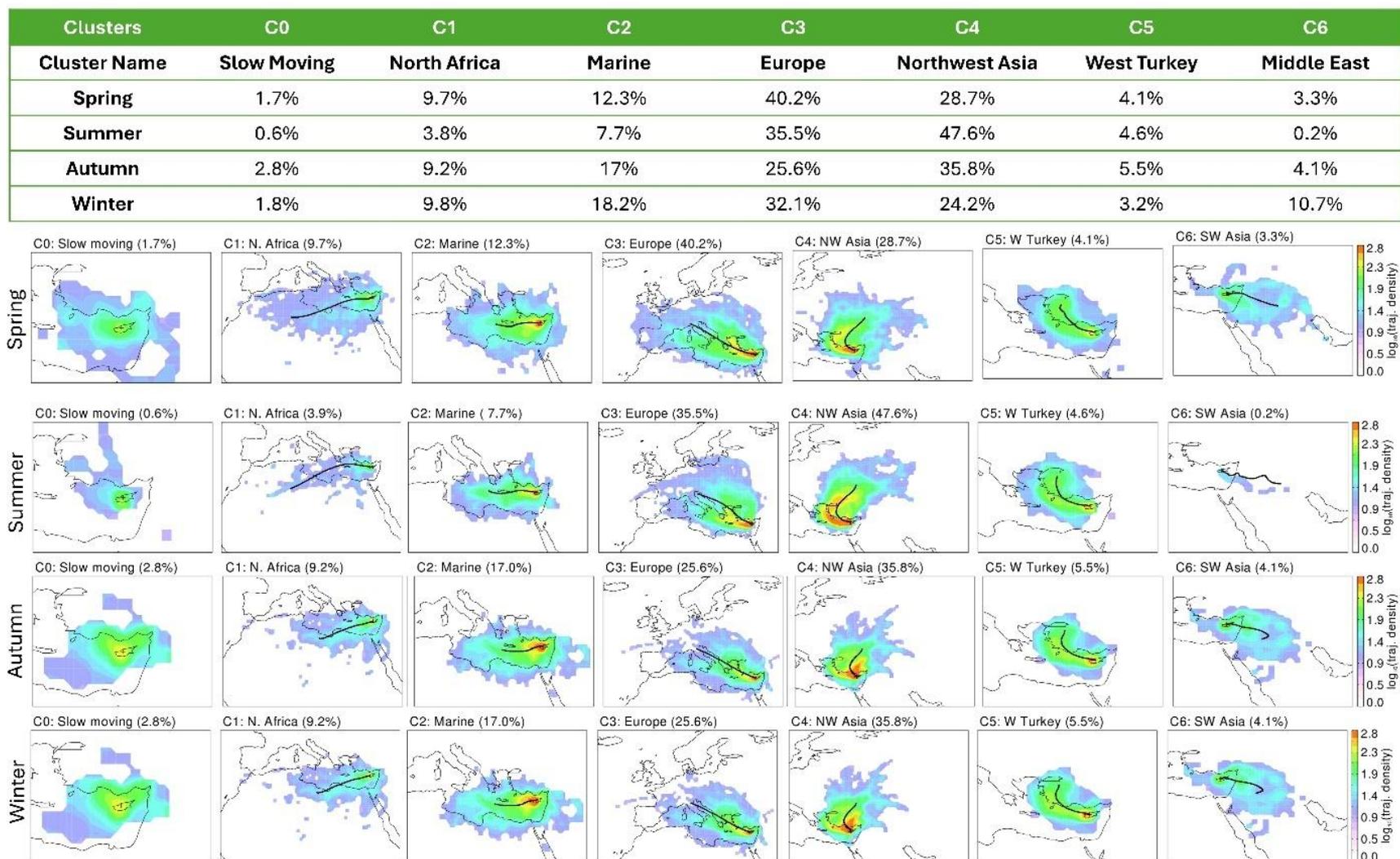


Figure S9: Seasonal distribution of air mass back-trajectory clusters (2022–2024). This figure represents seasonal cluster analysis of 5-day air mass back-trajectories arriving at the Cyprus regional background monitoring station for the years 2022–2024, using the HYSPLIT model. Seven major clusters (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.

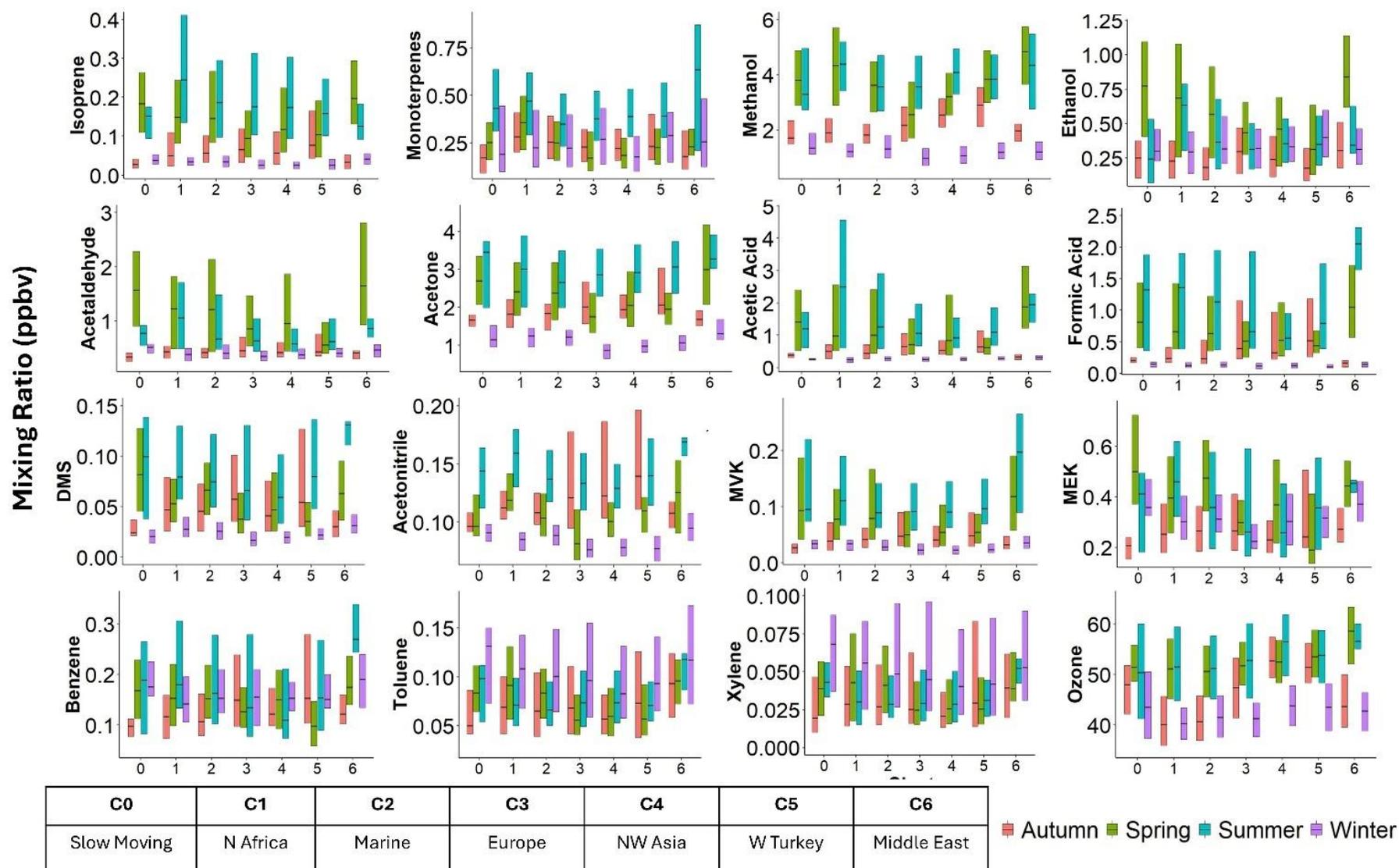


Figure S10: Seasonal mixing ratios of VOCs, and selected air pollutants across air mass clusters. Boxplots showing the distribution of mixing ratios of selected VOCs, and other air pollutants for different air mass clusters (C0–C6) identified by back trajectory analysis. Clusters represent different 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.

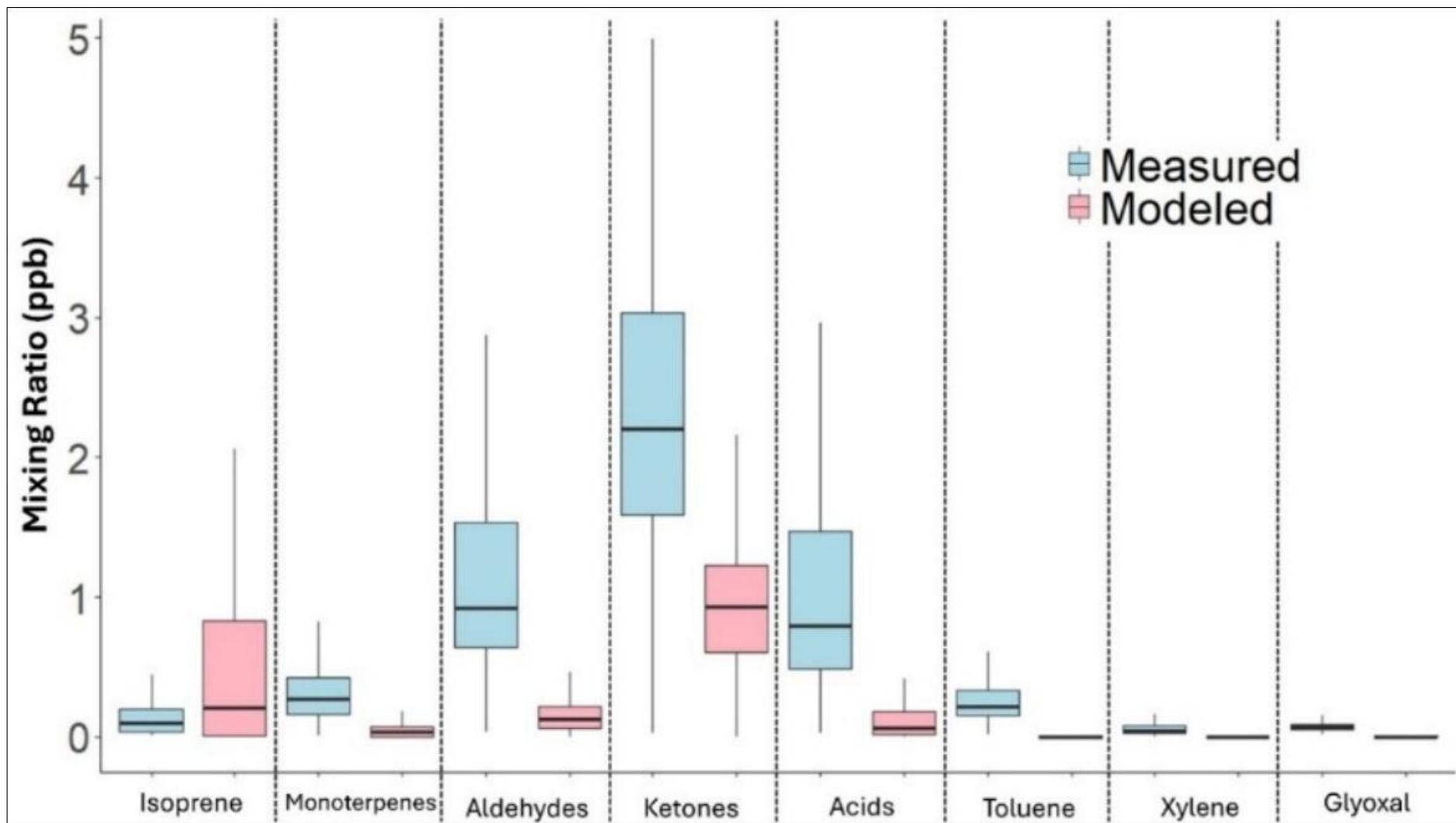


Figure S11: Comparison of measured and modeled volatile organic compound (VOC) mixing ratios in Cyprus.

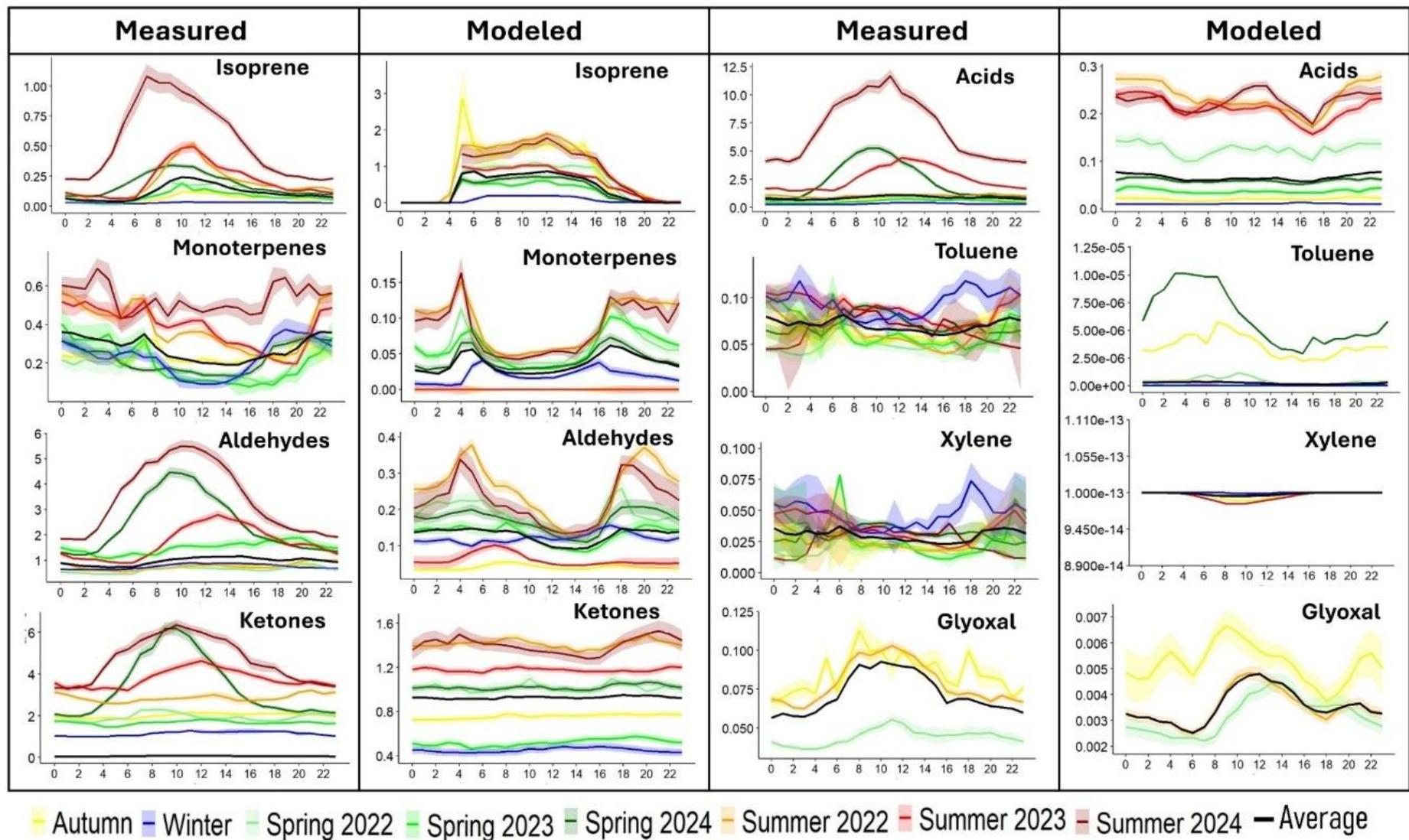


Figure S12: Diurnal and seasonal variability among measured and simulated VOCs mixing ratios (in ppbv).