



Supplement of

Urban ozone trends in Europe and the USA (2000–2021)

Beth S. Nelson and Will S. Drysdale

Correspondence to: Beth S. Nelson (beth.nelson@york.ac.uk) and Will S. Drysdale (will.drysdale@york.ac.uk)

The copyright of individual parts of the supplement might differ from the article licence.

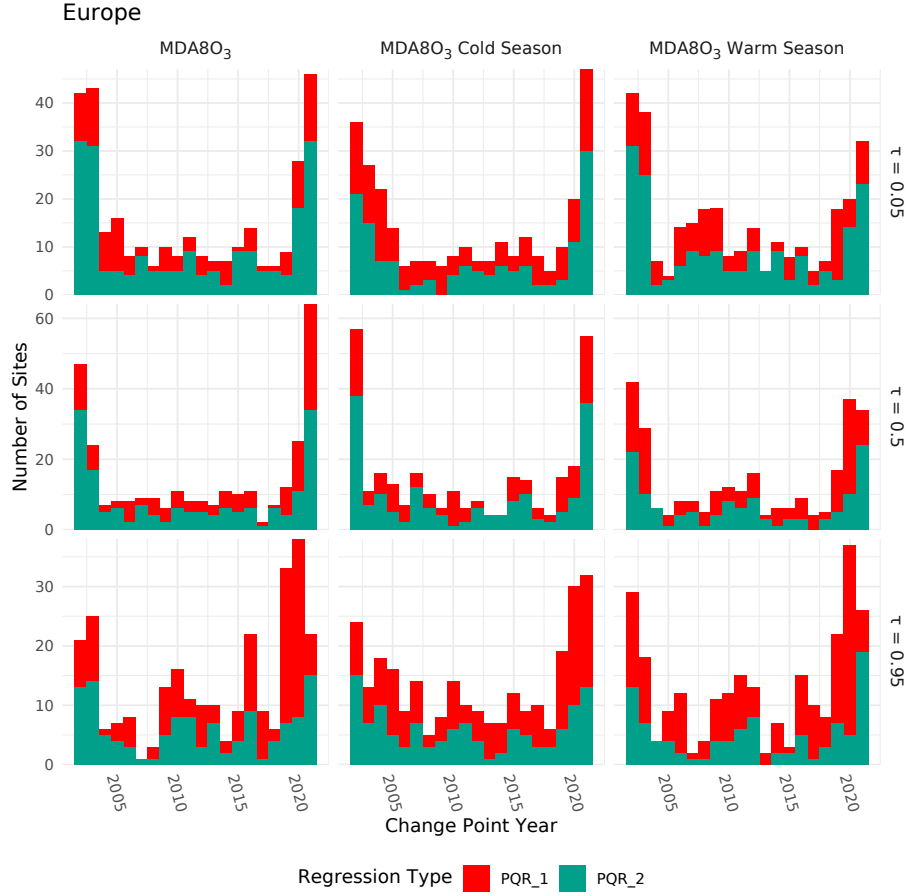


Figure S1: Years where change points have been assigned in MDA8O₃ all, cold and warm season (left to right) for sites in Europe. Top to bottoms shows $\tau = 0.05, 0.5, 0.95$. Stacked areas separate change points by PQR_1 (red) and PQR_2 (green)

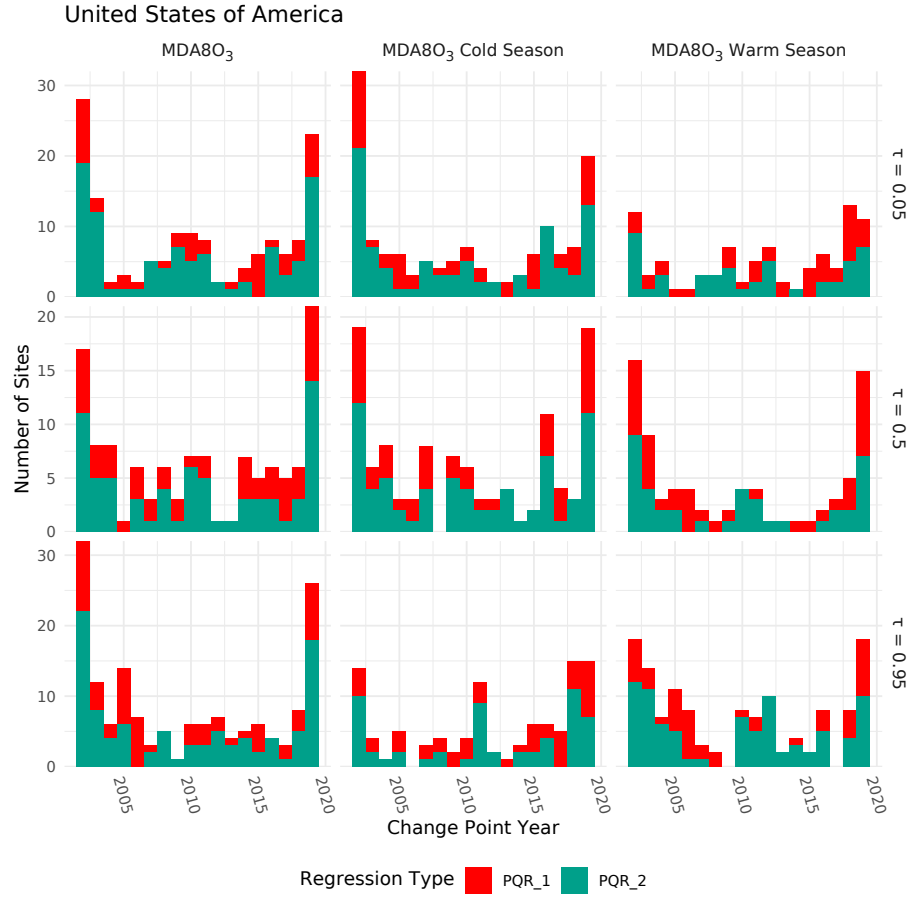


Figure S2: Years where change points have been assigned in MDA8O₃ all, cold and warm season (left to right) for sites in the USA. Top to bottoms shows $\tau = 0.05, 0.5, 0.95$. Stacked areas separate change points by PQR_1 (red) and PQR_2 (green)

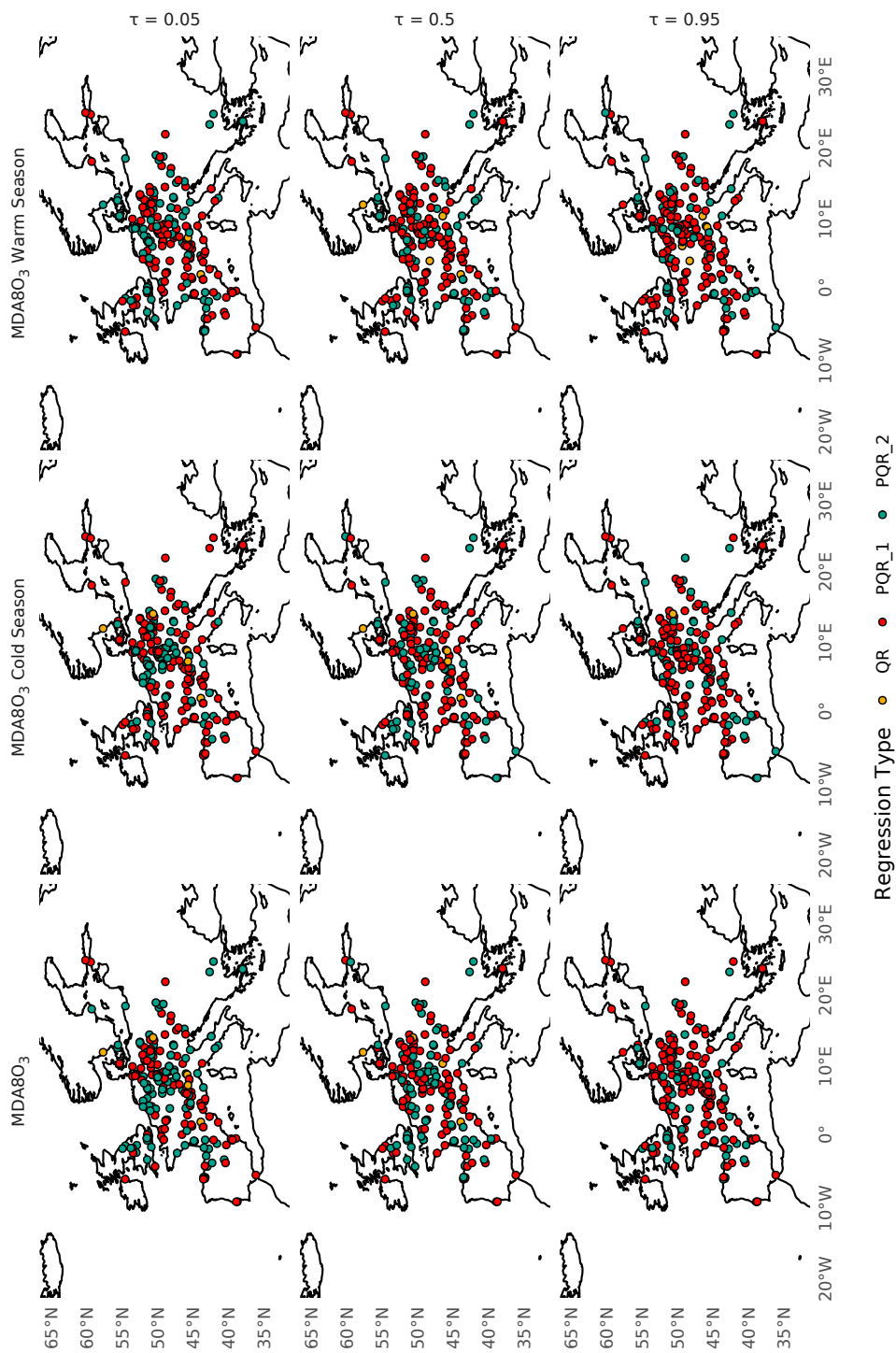


Figure S3: Sites in Europe showing type of the QR used at that site, by τ and MDA8O₃ type.

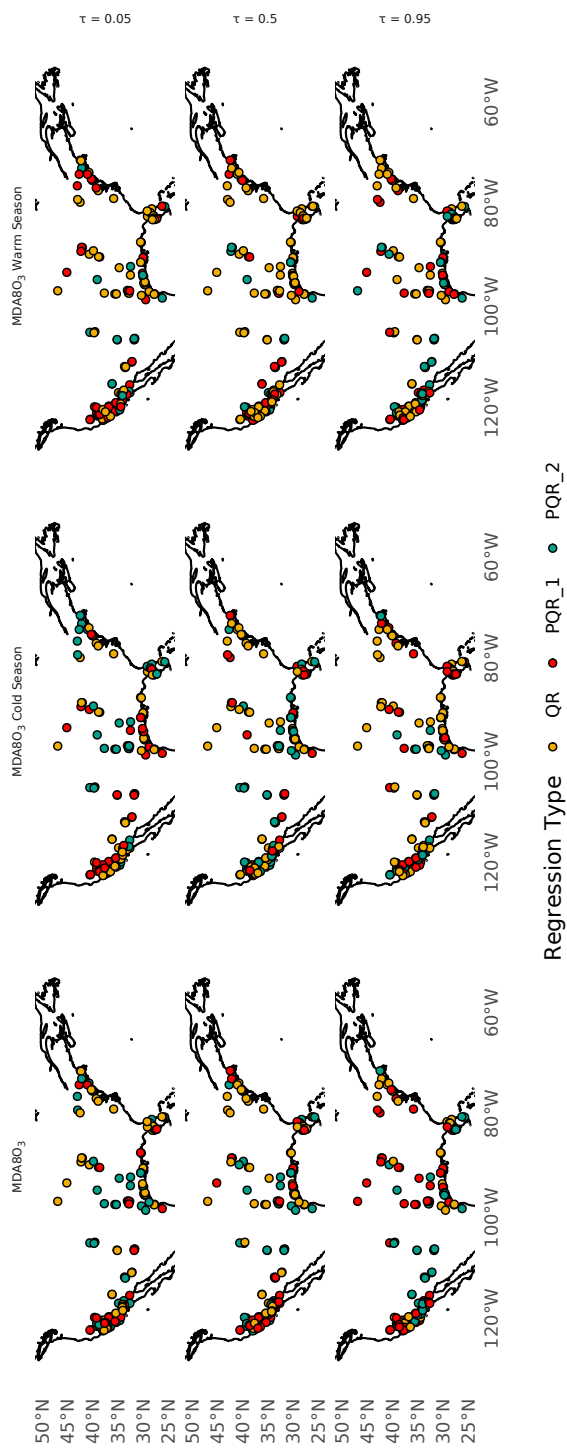


Figure S4: Sites in the USA showing type of the QR used at that site, by τ and MDA8O₃ type.

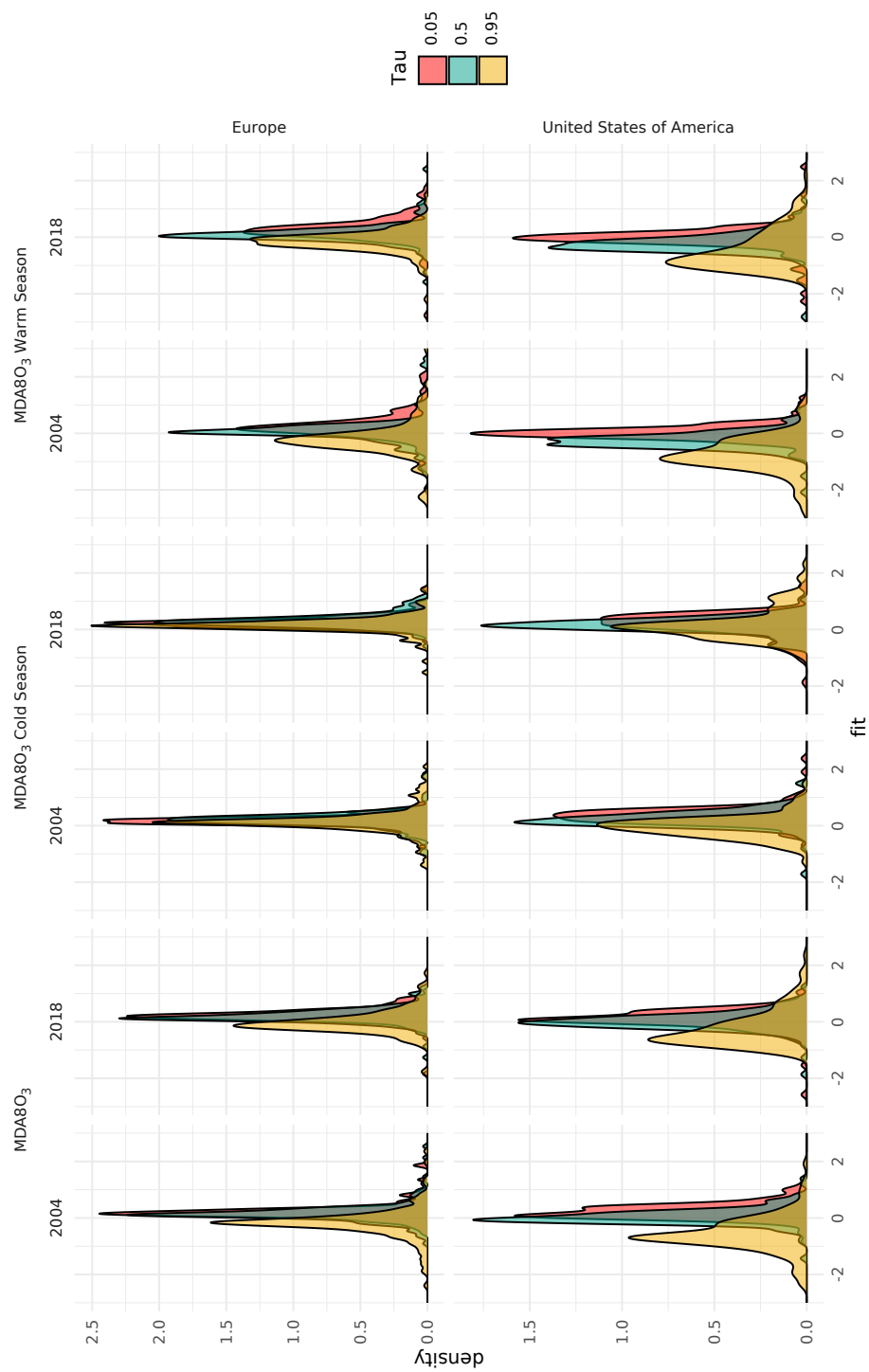


Figure S5: Distribution of sites for each MDA8O₃ type, all, cold and warm season from left to right, coloured by tau.

MDA8O₃

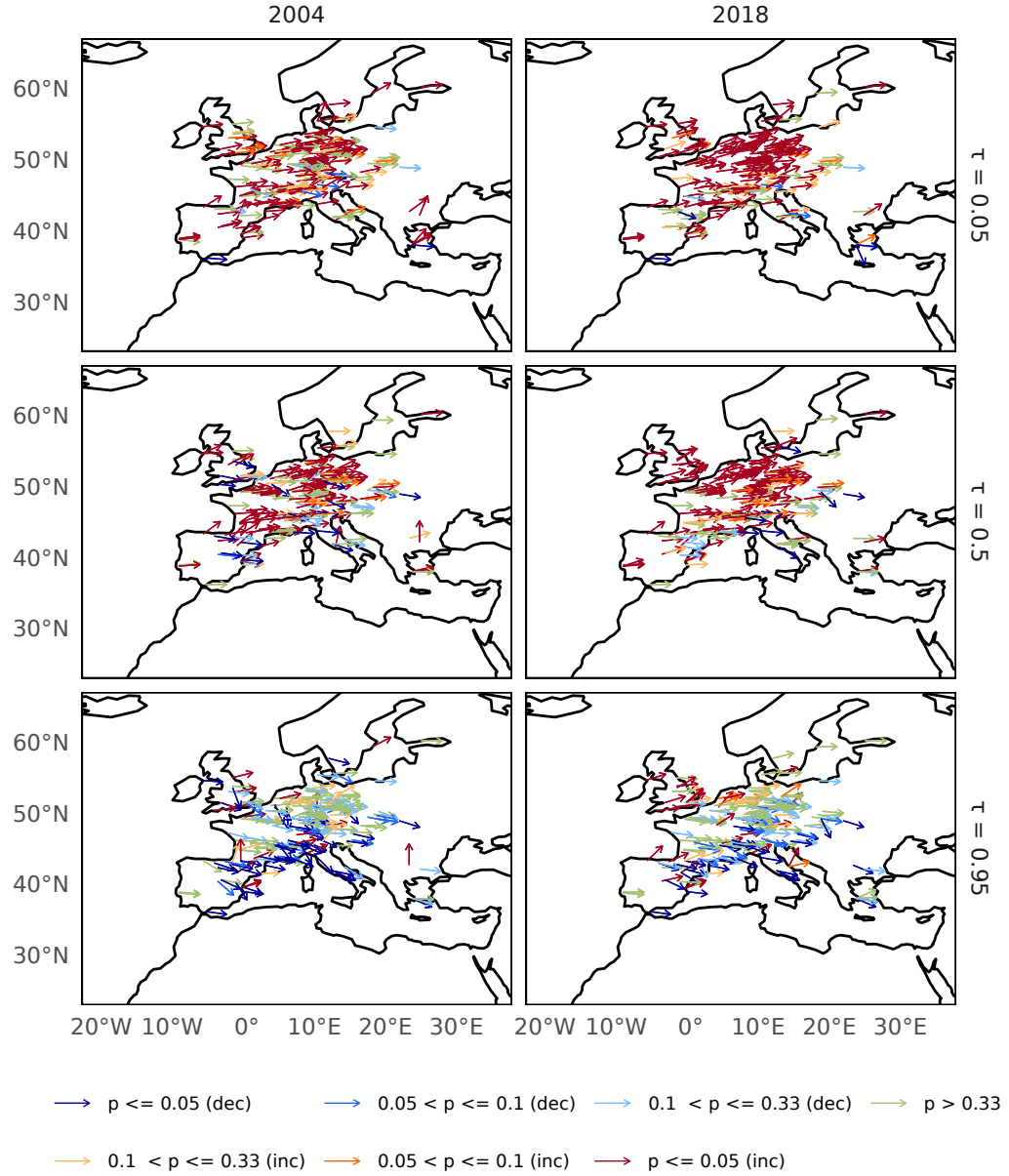


Figure S6: Trends in MDA8O₃ in Europe in 2004 (left) and 2018 (right). Trends are shown by an arrow where the angle between vertically up and horizontal corresponds to 2.5 - 0 ppbv / yr⁻¹, and between horizontal and vertically down corresponds to 0 - -2.5 ppbv / yr⁻¹. The few trends that have a magnitude greater than 2.5 ppbv have been clamped. Colour corresponds to the direction and significance of the trend.

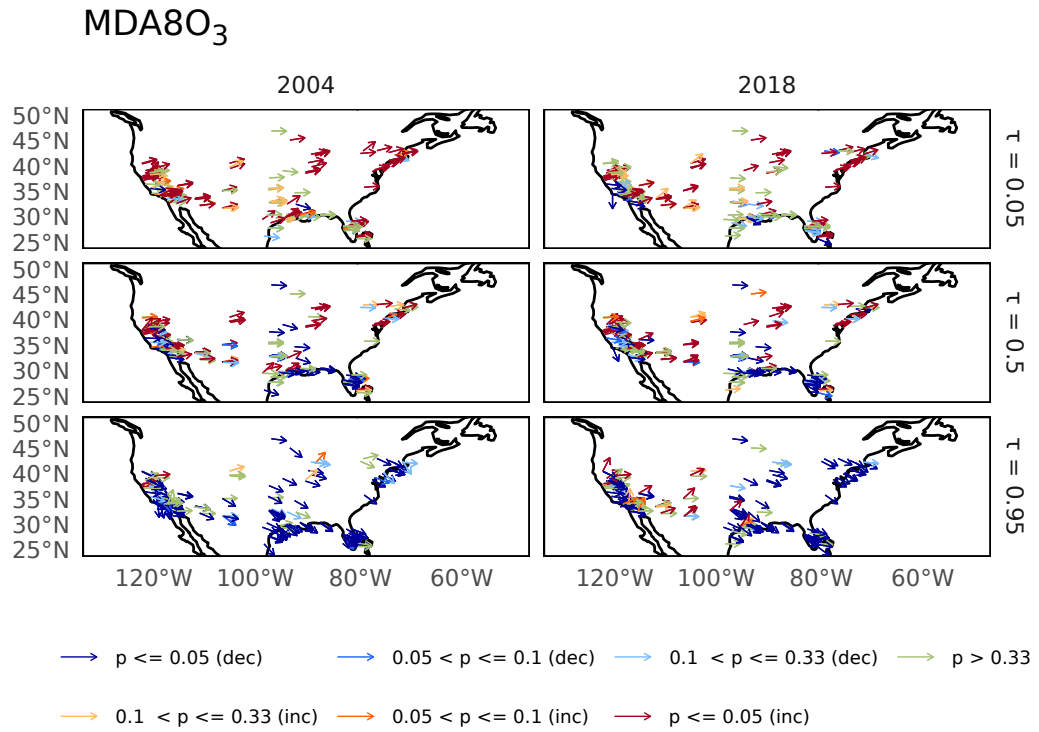


Figure S7: Trends in MDA8O₃ in the United States of America in 2004 (left) and 2018 (right), for $\tau = 0.05, 0.50$ and 0.95 (top to bottom). Trends are shown by an arrow where the angle between vertically up and horizontal corresponds to $2.5 - 0$ ppbv / yr⁻¹, and between horizontal and vertically down corresponds to $0 - -2.5$ ppbv / yr⁻¹. The few trends that have a magnitude greater than 2.5 ppbv have been clamped. Colour corresponds to the direction and significance of the trend.

MDA8O₃ Cold Season

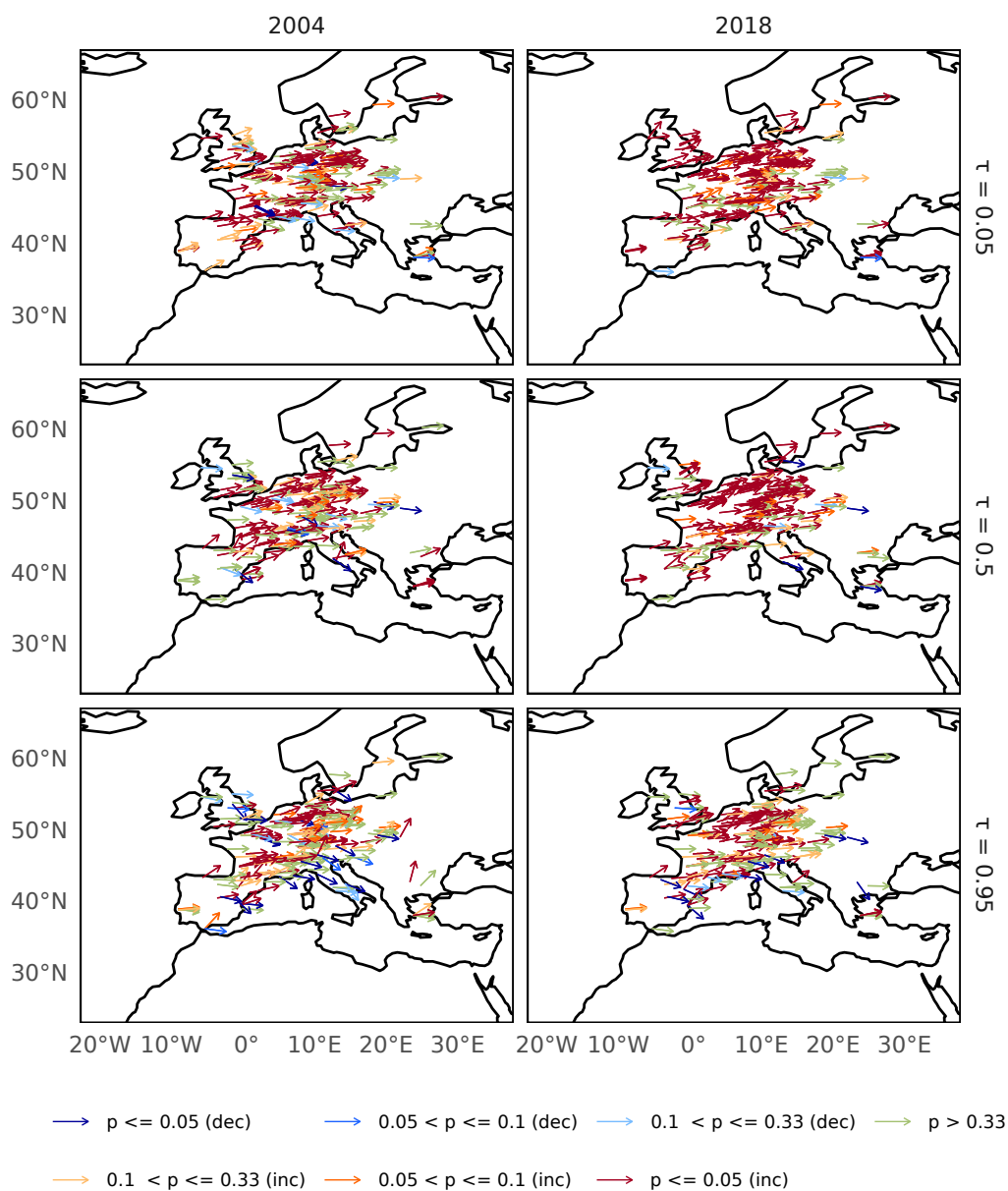


Figure S8: Trends in cold season MDA8O₃ in Europe in 2004 (left) and 2018 (right), for $\tau = 0.05, 0.50$ and 0.95 (top to bottom). Trends are shown by an arrow where the angle between vertically up and horizontal corresponds to 2.5 - 0 ppbv / yr⁻¹, and between horizontal and vertically down corresponds to 0 - -2.5 ppbv / yr⁻¹. The few trends that have a magnitude greater than 2.5 ppbv have been clamped. Colour corresponds to the direction and significance of the trend.

MDA8O₃ Cold Season

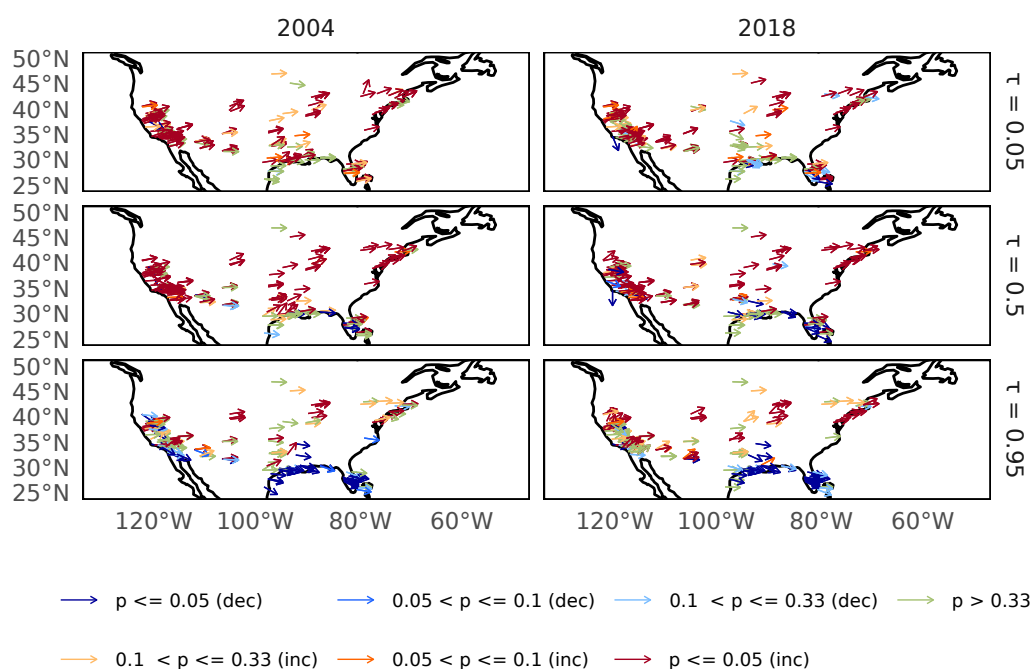


Figure S9: Trends in cold season MDA8O₃ in the United States of America in 2004 (left) and 2018 (right), for $\tau = 0.05, 0.50$ and 0.95 (top to bottom). Trends are shown by an arrow where the angle between vertically up and horizontal corresponds to $2.5 - 0 \text{ ppbv / yr}^{-1}$, and between horizontal and vertically down corresponds to $0 - -2.5 \text{ ppbv / yr}^{-1}$. The few trends that have a magnitude greater than 2.5 ppbv have been clamped. Colour corresponds to the direction and significance of the trend.

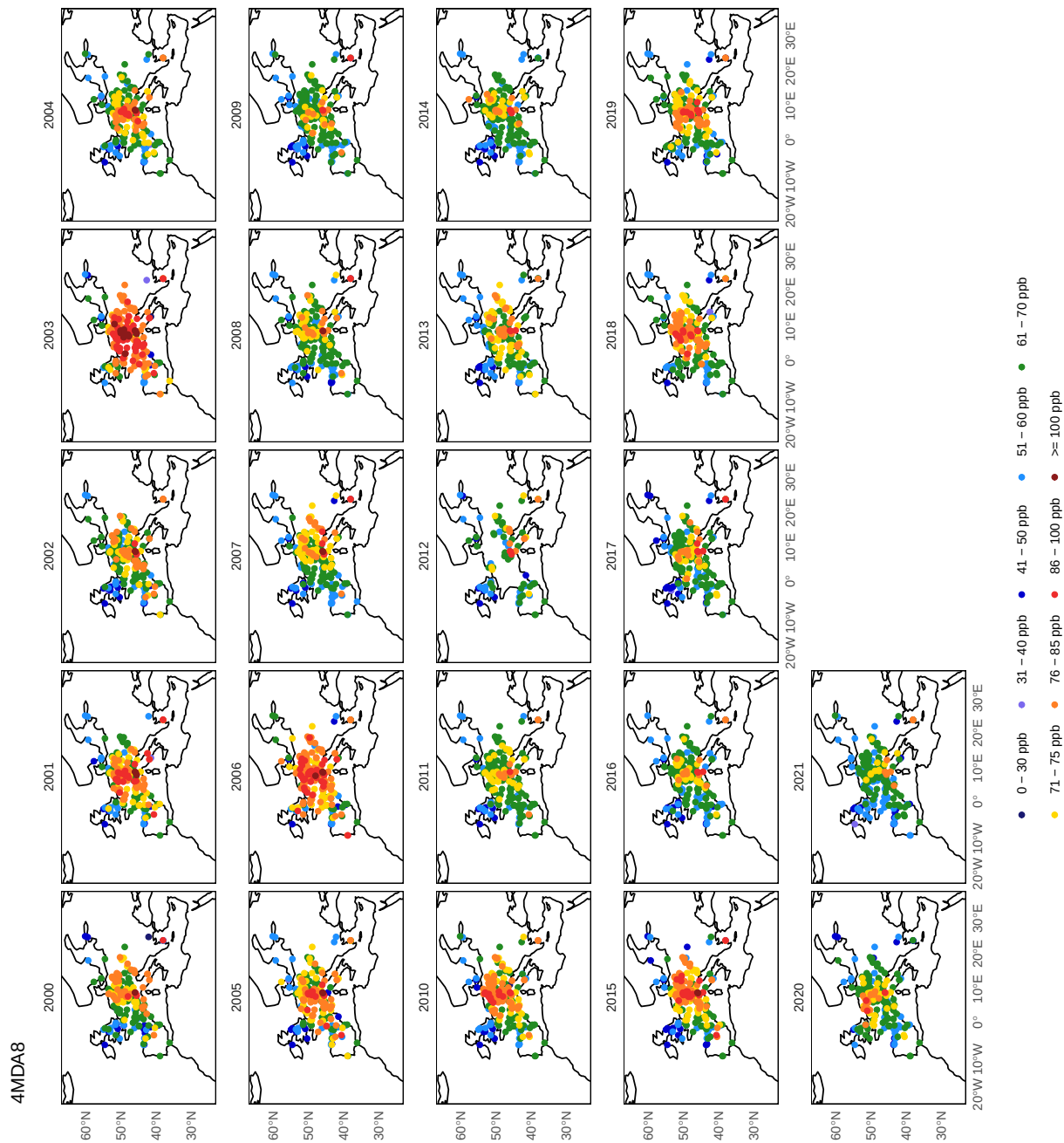


Figure S10: 4MDA8 values at sites in Europe between 2000 and 2021.

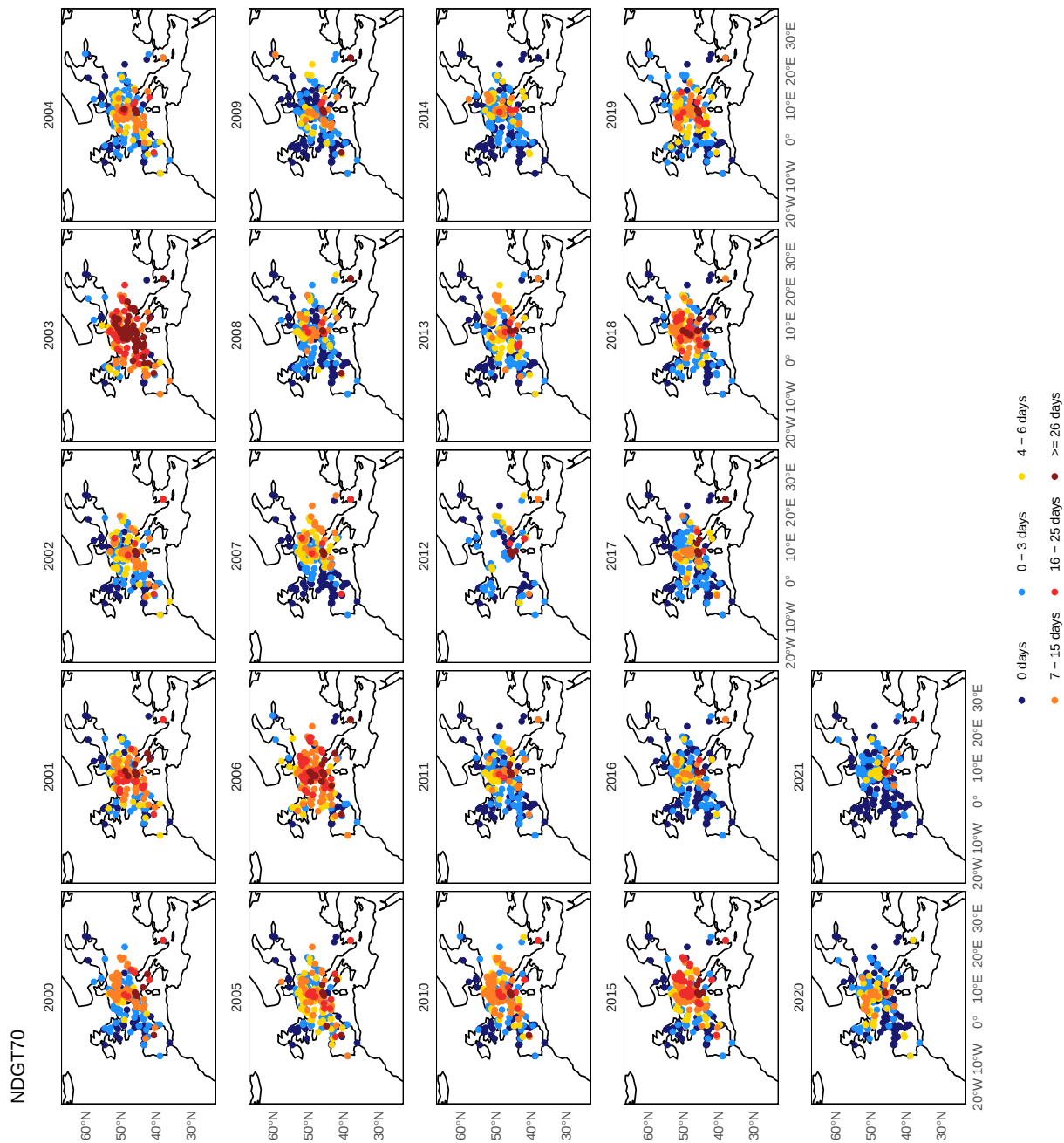


Figure S11: NDGT70 values at sites in Europe between 2000 and 2021.

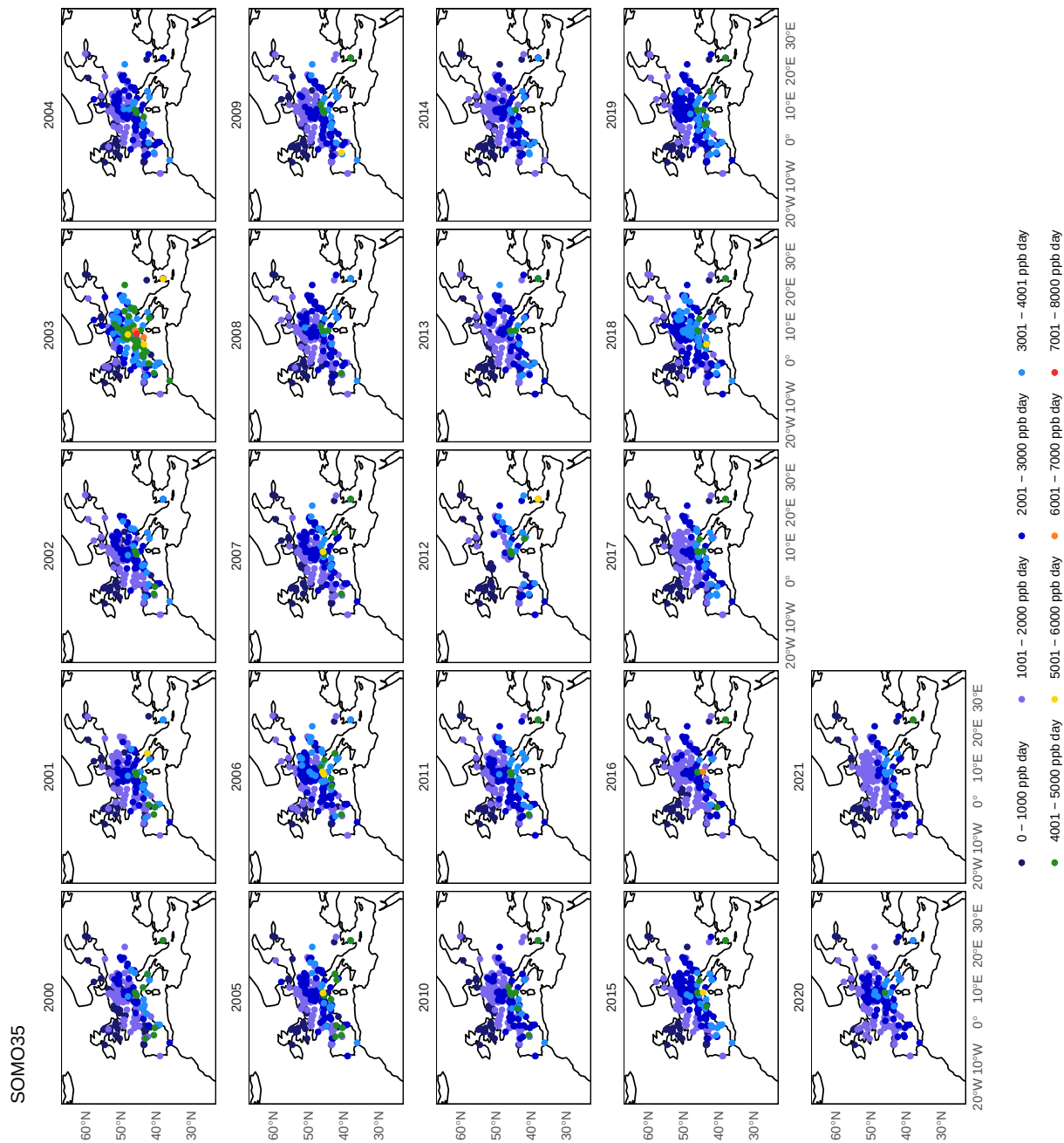


Figure S12: SOMO35 values at sites in Europe between 2000 and 2021.

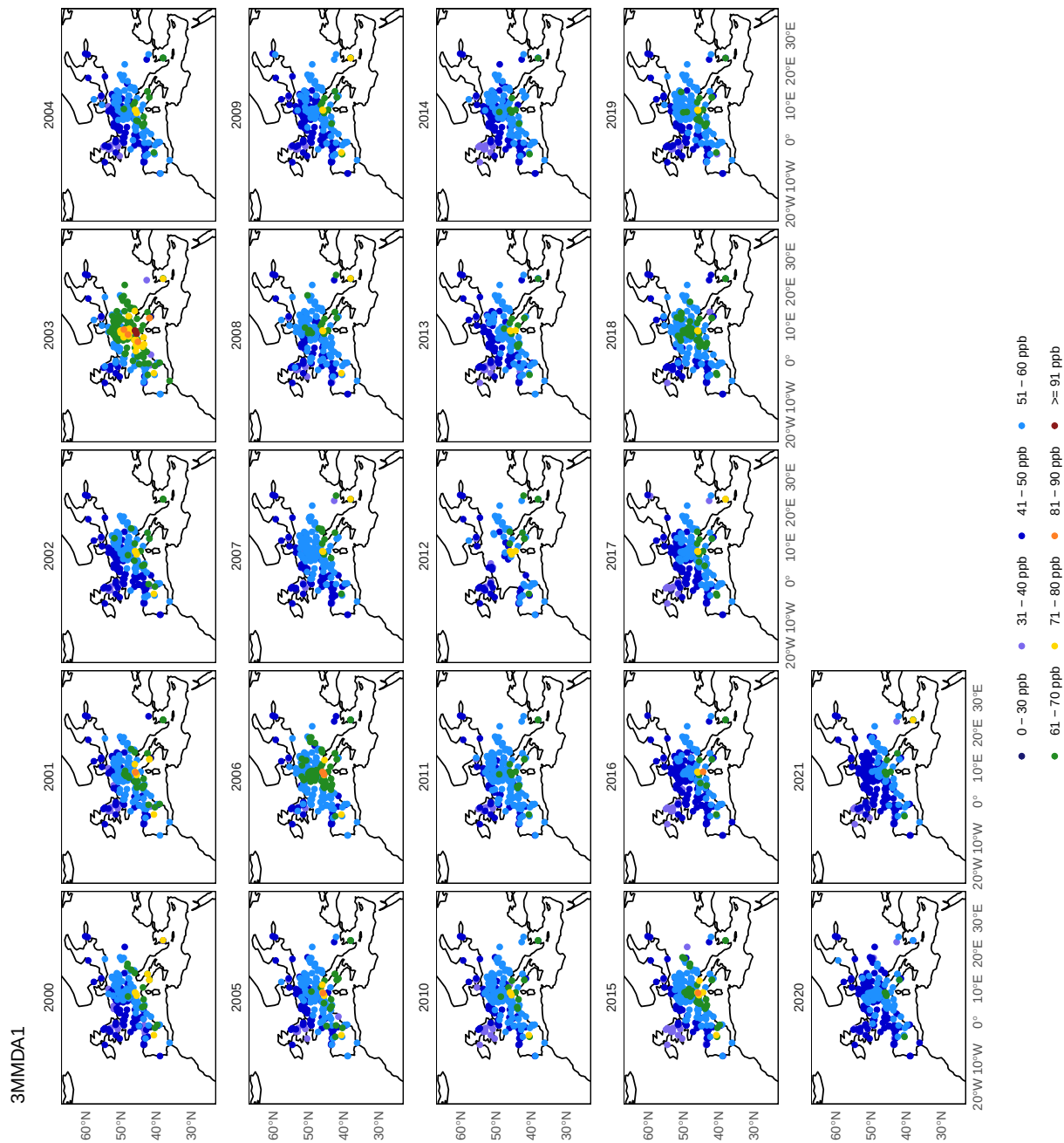


Figure S13: 3MMDA1 values at sites in Europe between 2000 and 2021.

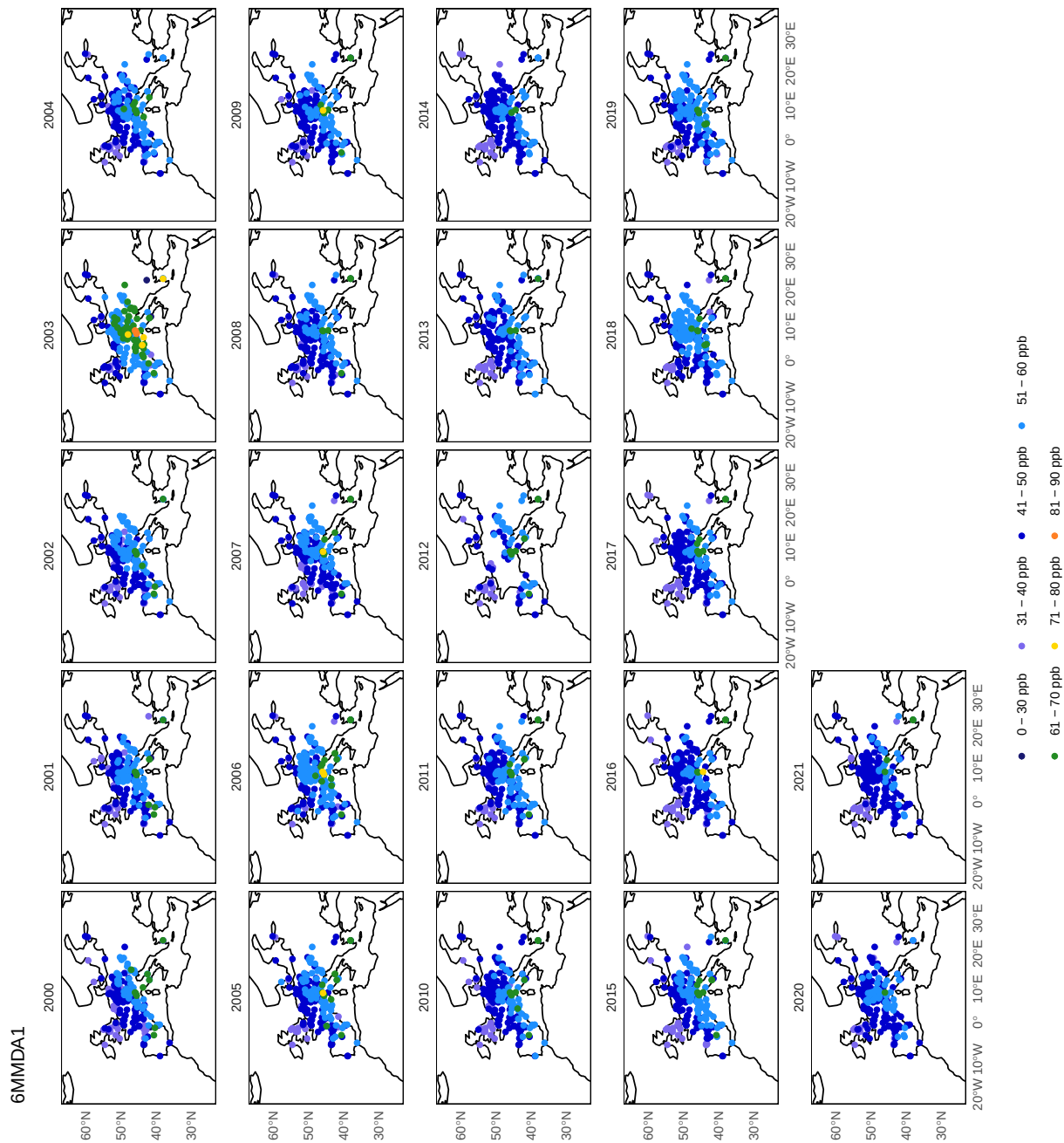


Figure S14: 6MMDA1 values at sites in Europe between 2000 and 2021.

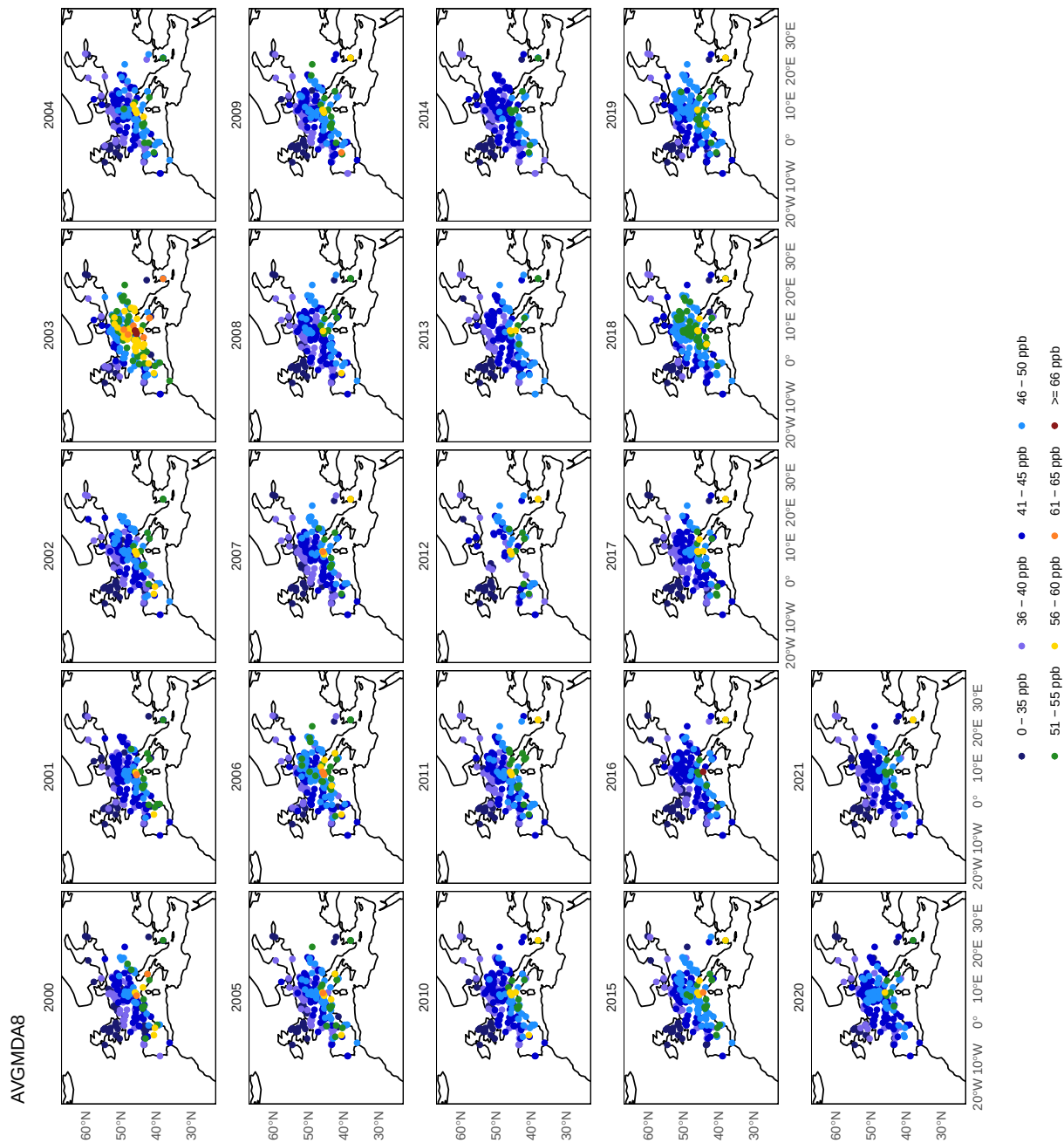


Figure S15: AVGMDA8 values at sites in Europe between 2000 and 2021.

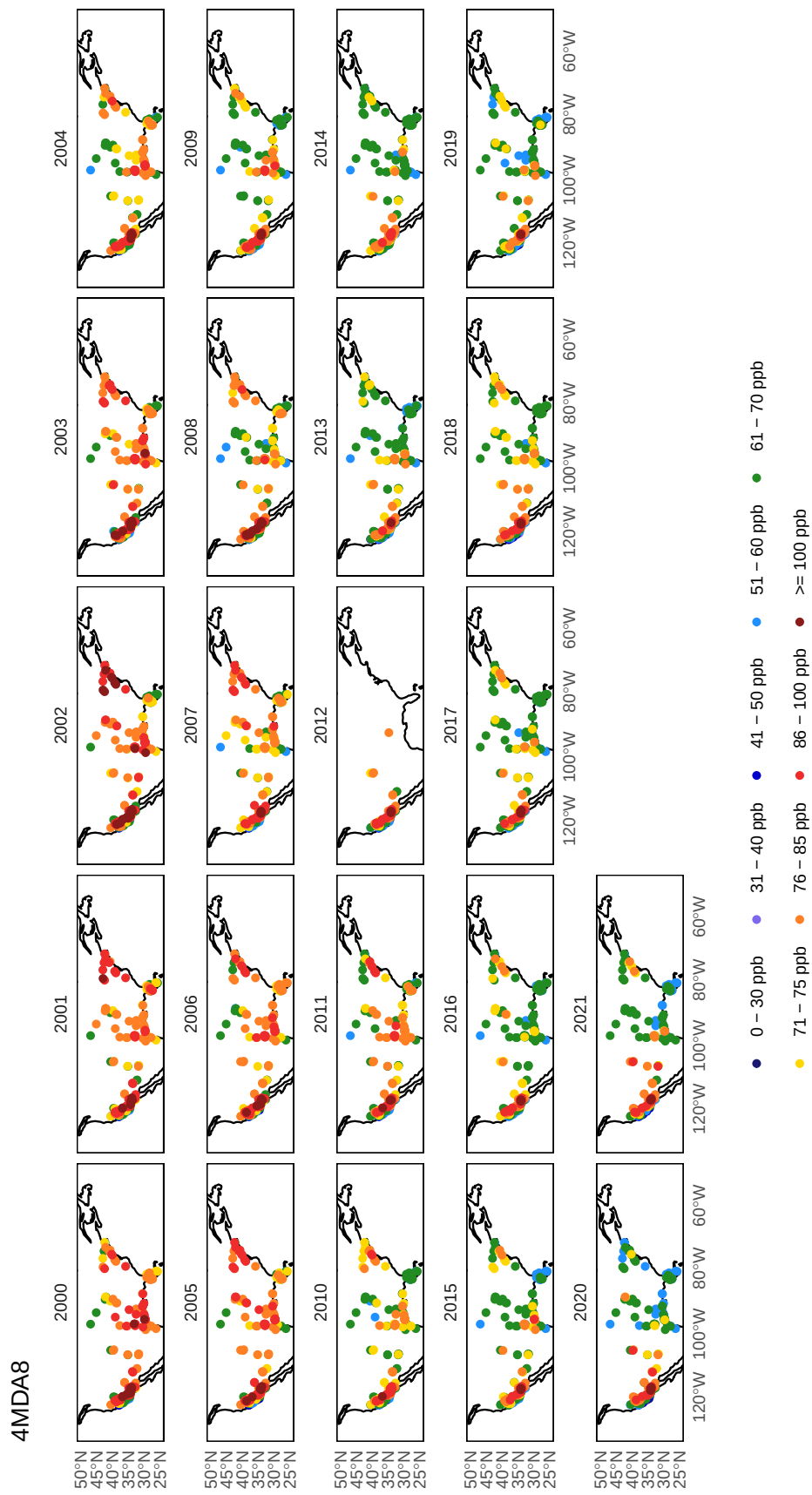


Figure S16: 4MDA8 values at sites in the USA between 2000 and 2021.

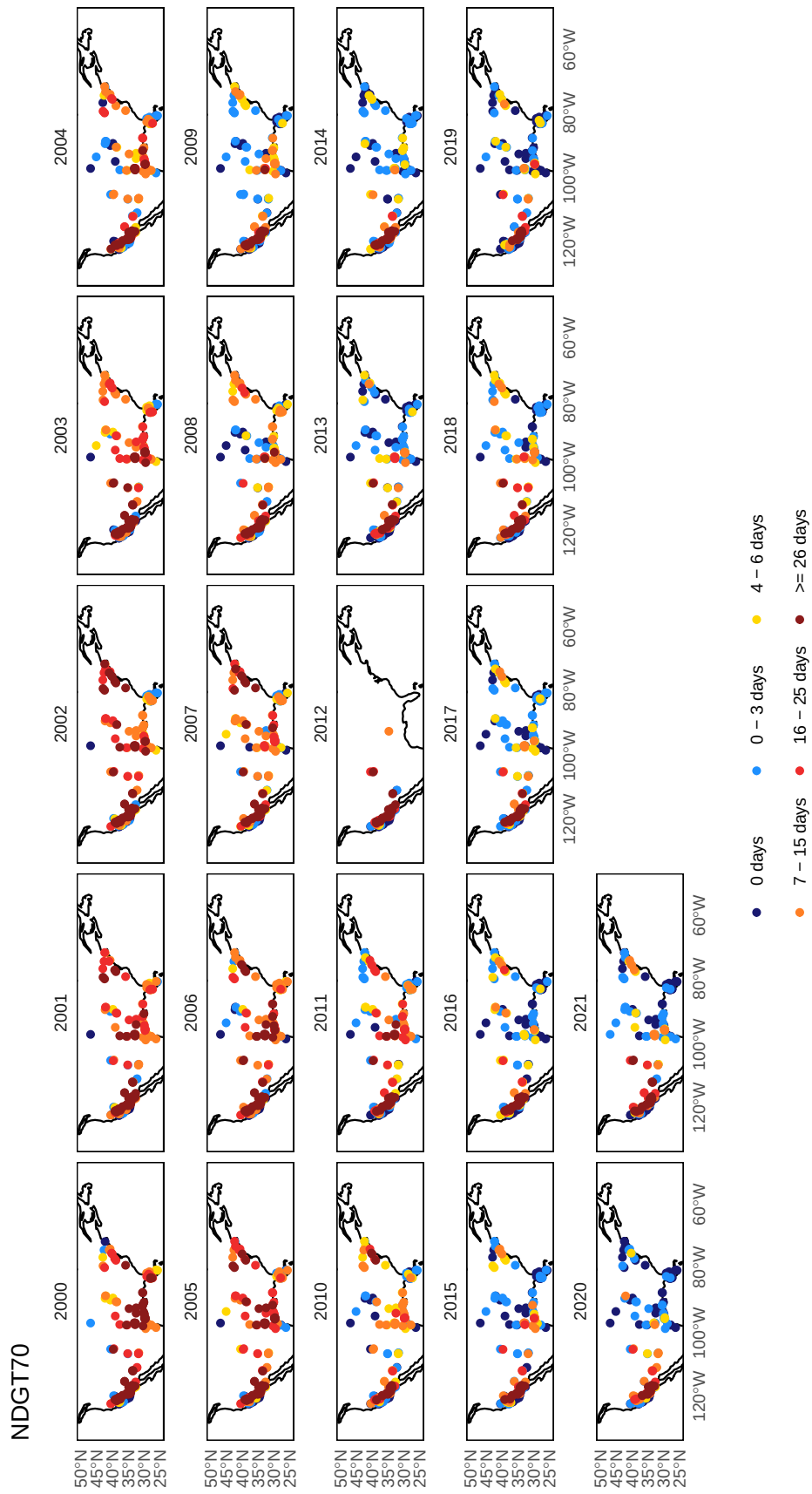


Figure S17: NDGT70 values at sites in the USA between 2000 and 2021.

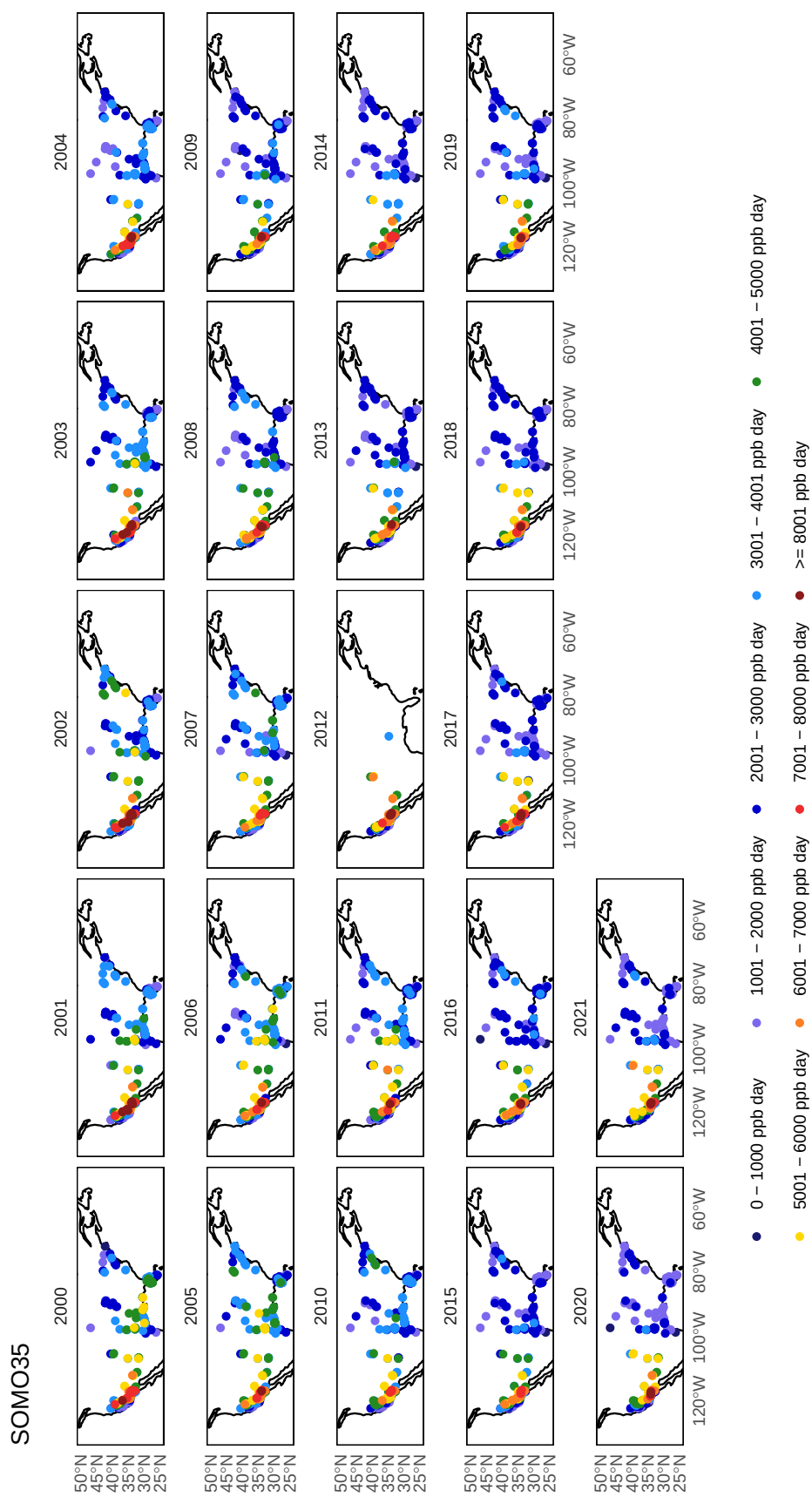


Figure S18: SOMO35 values at sites in the USA between 2000 and 2021.

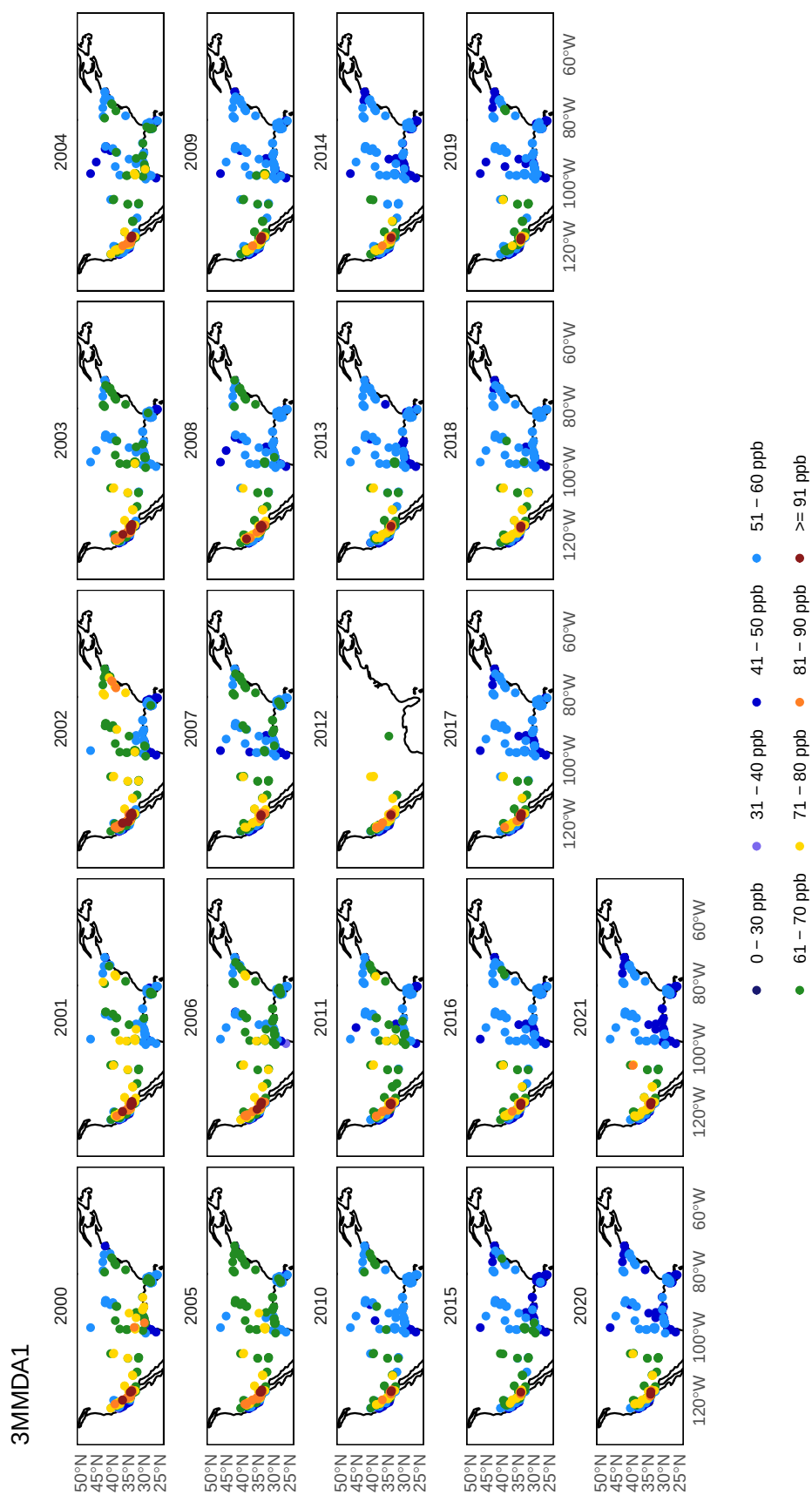


Figure S19: 3MMDA1 values at sites in the USA between 2000 and 2021.

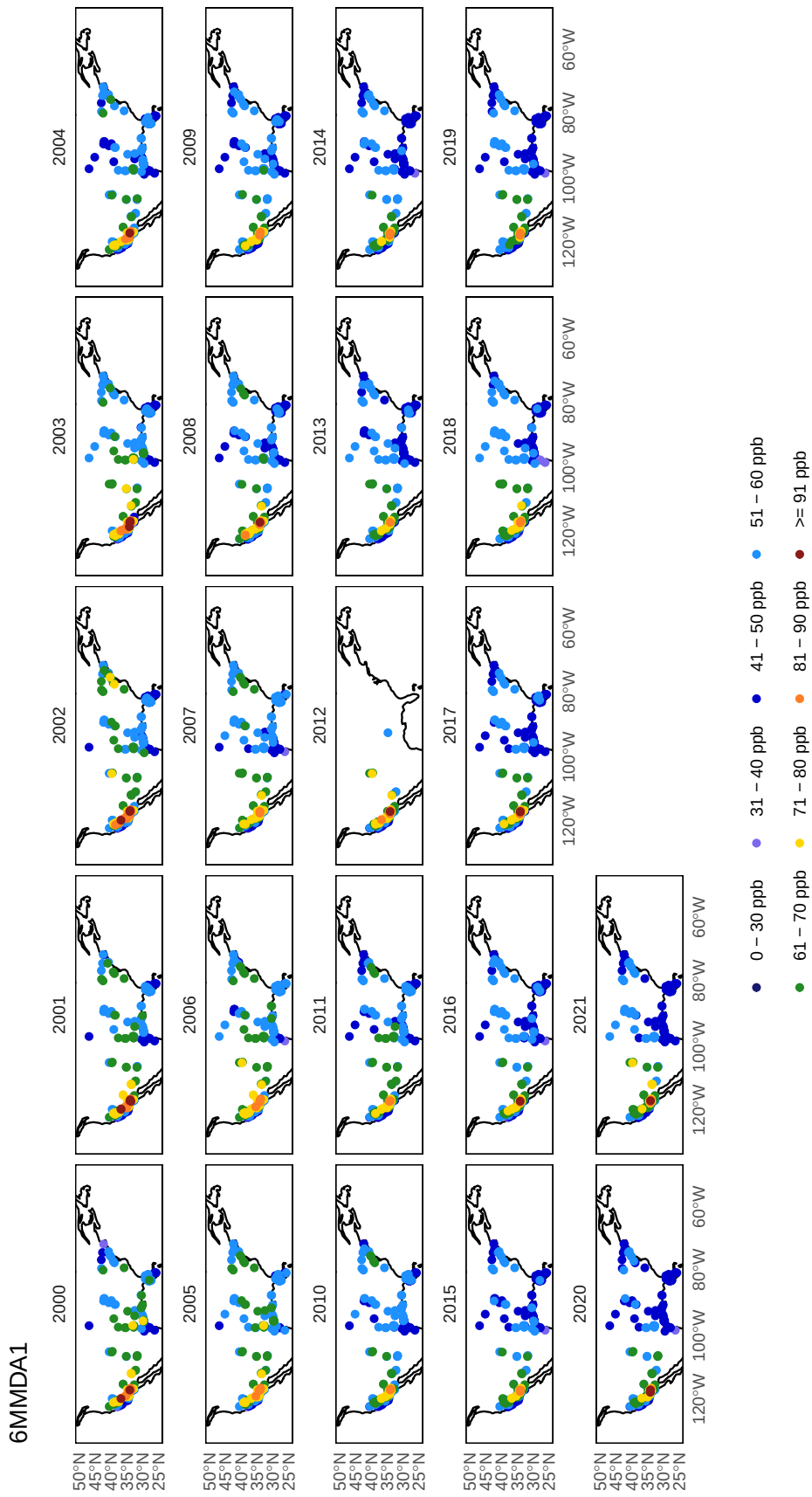


Figure S20: 6MMDA1 values at sites in the USA between 2000 and 2021.

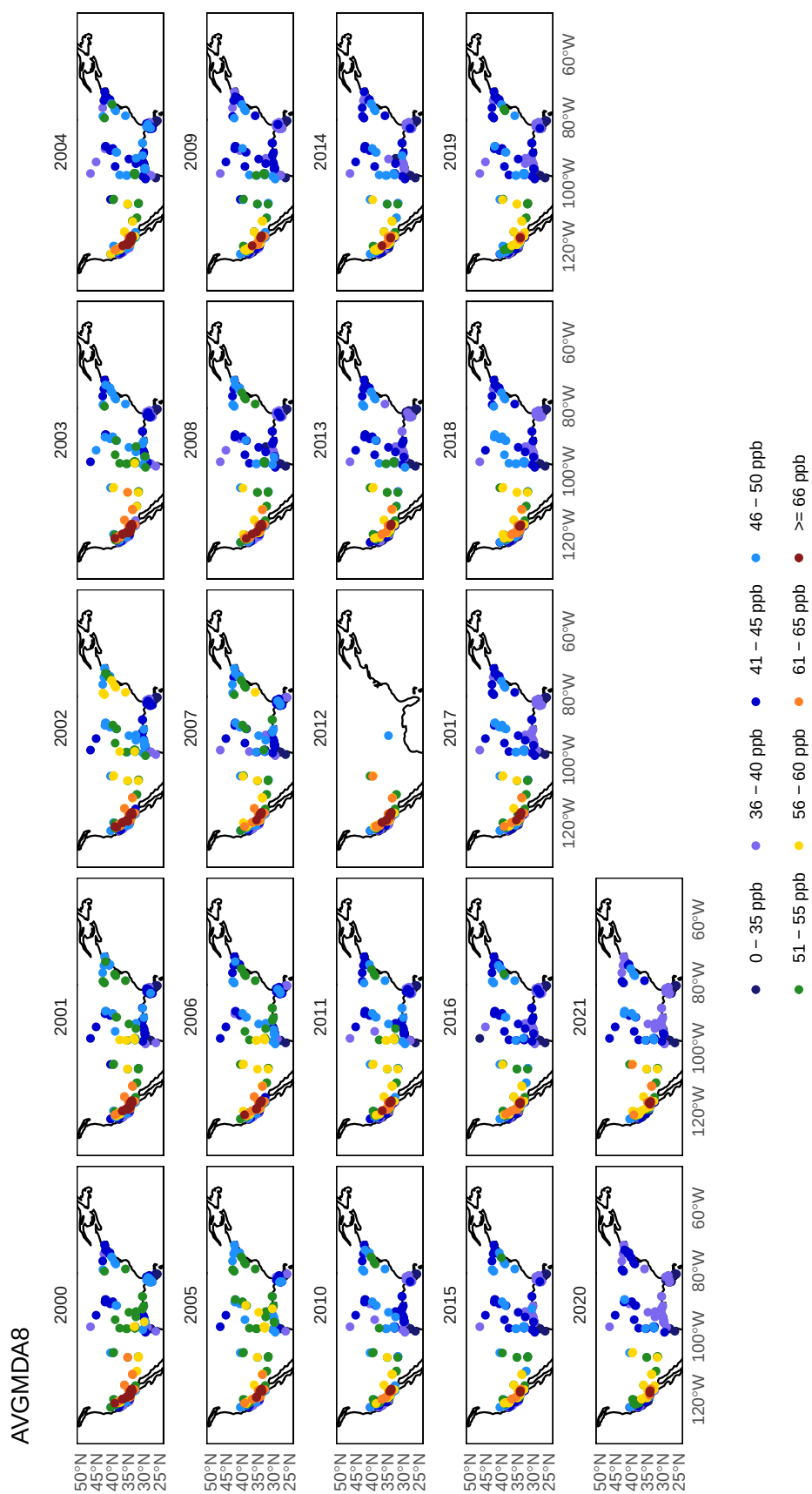


Figure S21: AVGMDA8 values at sites in the USA between 2000 and 2021.

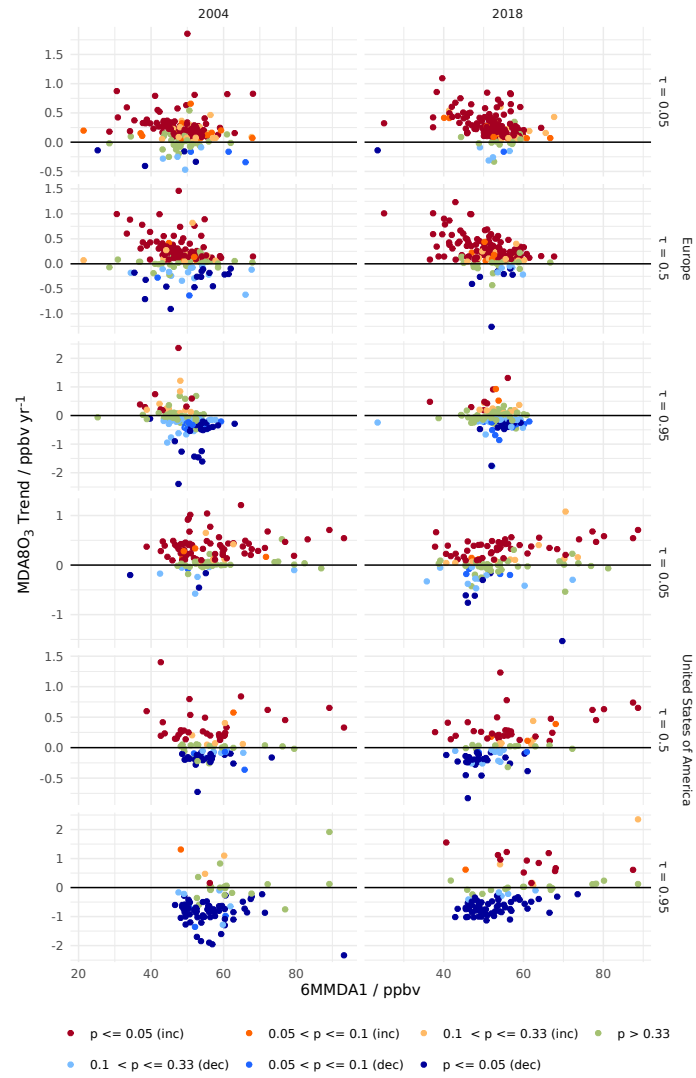


Figure S22: For the years 2004 (left) and 2018 (right) scatter plots show that years' MDA8O₃ trend in (top to bottom) Europe $\tau = 0.05, 0.5, 0.95$, United States of America $\tau = 0.05, 0.5, 0.95$ vs the 6MMDA1 for the same year. Colours show significance of trend.

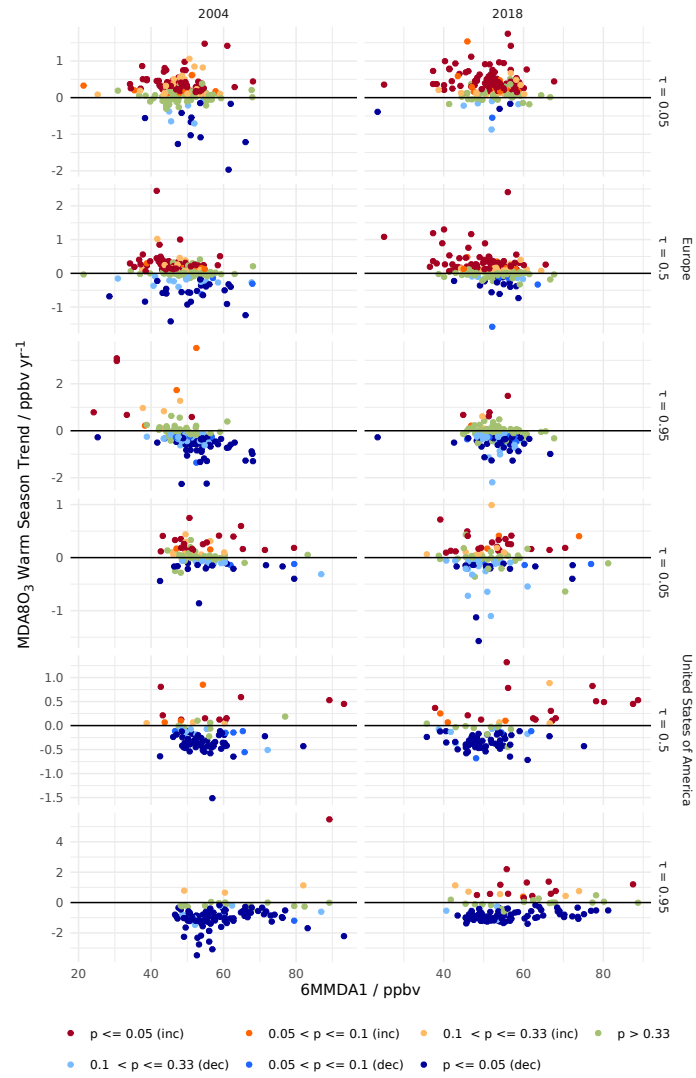


Figure S23: For the years 2004 (left) and 2018 (right) scatter plots show that years' warm season MDA8O₃ trend in (top to bottom) Europe $\tau = 0.05, 0.5, 0.95$, United States of America $\tau = 0.05, 0.5, 0.95$ vs the 6MMDA1 for the same year. Colours show significance of trend.

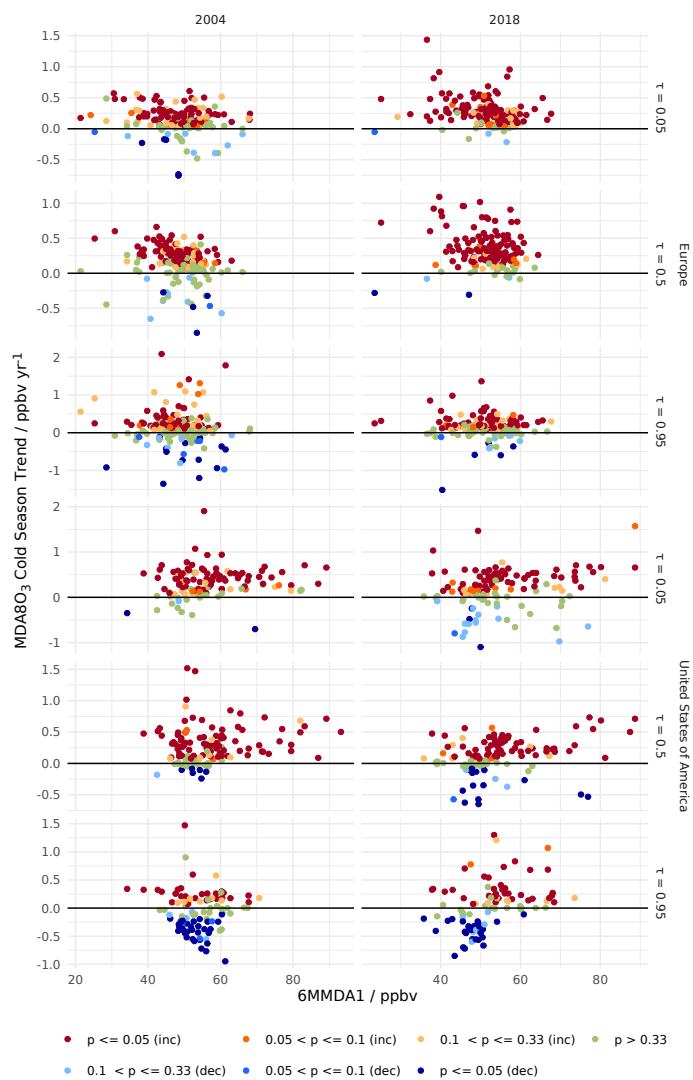


Figure S24: For the years 2004 (left) and 2018 (right) scatter plots show that years' cold season MDA8O₃ trend in (top to bottom) Europe $\tau = 0.05, 0.5, 0.95$, United States of America $\tau = 0.05, 0.5, 0.95$ vs the 6MMDA1 for the same year. Colours show the significance of the trend.

Table S1: List of Sites Used

Region	Station ID	Station Type	Latitude	Longitude
United States of America	1138	urban	29.670	-95.129
United States of America	1149	suburban	29.723	-95.636
United States of America	1162	suburban	29.901	-95.326
United States of America	1163	suburban	29.696	-95.499
United States of America	1164	suburban	29.624	-95.474
United States of America	1169	suburban	29.626	-95.267
United States of America	1206	urban	34.894	-117.025
United States of America	14337	suburban	33.560	-112.066
United States of America	14340	suburban	33.706	-111.856
United States of America	14348	suburban	32.204	-110.878
United States of America	14356	urban	34.756	-92.281
United States of America	14365	suburban	37.936	-122.026
United States of America	14371	suburban	36.705	-119.741
United States of America	14373	suburban	36.842	-119.875
United States of America	14374	urban	36.819	-119.716
United States of America	14382	suburban	35.504	-119.273
United States of America	14386	suburban	34.144	-117.850
United States of America	14389	suburban	34.199	-118.533
United States of America	14422	suburban	33.853	-116.541
United States of America	14433	suburban	34.416	-117.286
United States of America	14434	suburban	34.060	-117.147
United States of America	14470	urban	34.638	-120.458
United States of America	14474	urban	37.227	-121.980
United States of America	14479	suburban	40.550	-122.381
United States of America	14490	suburban	39.139	-121.619
United States of America	14509	suburban	39.568	-104.957
United States of America	14519	suburban	40.577	-105.079
United States of America	14548	suburban	30.368	-87.271
United States of America	14550	suburban	27.928	-82.455
United States of America	14551	suburban	27.893	-82.538
United States of America	14565	suburban	27.786	-82.740
United States of America	14567	suburban	27.307	-82.570
United States of America	14568	suburban	28.746	-81.311
United States of America	14580	urban	21.303	-157.871

United States of America	14596	suburban	42.049	-88.273
United States of America	14604	suburban	42.221	-88.242
United States of America	14609	suburban	40.687	-89.607
United States of America	14613	suburban	38.612	-90.160
United States of America	14617	suburban	42.335	-89.038
United States of America	14655	urban	37.702	-97.315
United States of America	14680	urban	32.535	-93.747
United States of America	14540	suburban	28.311	-80.615
United States of America	14543	suburban	26.291	-80.096
United States of America	14544	suburban	26.088	-80.111
United States of America	14547	suburban	30.525	-87.204
United States of America	14557	suburban	25.733	-80.162
United States of America	14564	suburban	27.947	-82.732
United States of America	14682	suburban	30.140	-93.368
United States of America	14686	urban	30.420	-91.182
United States of America	14701	suburban	30.501	-91.214
United States of America	14729	suburban	42.194	-72.555
United States of America	1474	suburban	33.480	-111.917
United States of America	14771	suburban	45.138	-93.208
United States of America	14827	suburban	35.185	-106.508
United States of America	14834	suburban	42.681	-73.757
United States of America	14840	suburban	42.993	-78.772
United States of America	14852	suburban	43.052	-76.059
United States of America	14857	suburban	40.745	-73.419
United States of America	14860	suburban	41.052	-73.764
United States of America	14911	suburban	35.320	-97.484
United States of America	14914	suburban	35.614	-97.475
United States of America	14944	suburban	40.076	-75.012
United States of America	14988	suburban	29.515	-98.620
United States of America	15006	suburban	30.036	-94.071
United States of America	15007	urban	29.898	-93.991
United States of America	15009	suburban	27.832	-97.555
United States of America	15010	urban	30.085	-93.761
United States of America	15012	suburban	30.355	-97.762
United States of America	15014	urban	28.836	-97.006
United States of America	15164	urban	32.295	-110.982
United States of America	15190	suburban	39.233	-121.056
United States of America	15197	suburban	33.921	-116.858

United States of America	15210	suburban	34.446	-119.828
United States of America	15215	suburban	40.453	-122.299
United States of America	15219	suburban	37.488	-120.836
United States of America	15222	suburban	38.661	-121.733
United States of America	15283	urban	27.481	-82.619
United States of America	15285	urban	29.171	-82.101
United States of America	15292	suburban	27.940	-82.000
United States of America	15293	suburban	28.029	-81.972
United States of America	15295	suburban	29.207	-81.052
United States of America	15357	urban	39.117	-94.636
United States of America	15376	urban	30.462	-91.179
United States of America	15400	urban	42.475	-70.971
United States of America	15406	urban	42.330	-71.083
United States of America	15454	suburban	31.796	-106.584
United States of America	15467	urban	42.500	-79.319
United States of America	15240	suburban	39.744	-105.178
United States of America	15284	suburban	27.450	-82.522
United States of America	15288	suburban	28.348	-81.636
United States of America	15291	suburban	28.196	-82.756
United States of America	15383	urban	32.510	-92.046
United States of America	15496	suburban	46.934	-96.855
United States of America	15560	suburban	33.132	-96.786
United States of America	15561	suburban	32.676	-96.872
United States of America	15565	suburban	31.786	-106.324
United States of America	15566	urban	31.766	-106.455
United States of America	15567	suburban	31.668	-106.288
United States of America	1635	urban	38.568	-121.493
United States of America	1692	urban	38.922	-77.013
United States of America	1710	suburban	39.867	-88.926
United States of America	1811	urban	37.982	-120.379
United States of America	1909	suburban	40.283	-74.743
United States of America	1969	suburban	27.350	-82.480
United States of America	2139	suburban	32.922	-97.282
United States of America	2202	suburban	32.842	-116.768
United States of America	2235	suburban	38.614	-121.368
United States of America	2275	urban	32.806	-97.357
United States of America	2337	suburban	38.683	-121.164
United States of America	2401	suburban	36.170	-115.263

United States of America	2407	suburban	38.861	-90.106
United States of America	2464	urban	37.688	-121.784
United States of America	2479	urban	38.103	-122.238
United States of America	2687	suburban	33.217	-117.396
United States of America	2746	suburban	35.856	-78.574
United States of America	2758	suburban	26.226	-98.291
United States of America	2919	suburban	27.765	-97.434
United States of America	3104	suburban	32.919	-96.808
United States of America	6313	urban	37.642	-120.994
United States of America	6314	urban	35.357	-119.063
United States of America	6315	suburban	35.438	-119.017
United States of America	6317	suburban	38.343	-120.764
United States of America	6319	suburban	35.615	-120.657
United States of America	7991	urban	39.250	-119.957
United States of America	8024	suburban	33.677	-117.331
United States of America	8035	urban	39.645	-119.840
United States of America	8070	suburban	34.448	-119.231
United States of America	8098	suburban	38.725	-120.822
United States of America	8138	suburban	38.746	-121.265
United States of America	8156	suburban	36.482	-121.733
United States of America	8163	suburban	34.107	-117.274
United States of America	8169	suburban	32.676	-115.483
United States of America	8197	suburban	34.276	-118.684
United States of America	8227	suburban	34.136	-117.924
United States of America	8241	suburban	34.210	-118.871
United States of America	8249	urban	34.104	-117.629
Europe	at51066	background	47.806	13.043
Europe	at60018	background	47.076	15.438
Europe	at60143	background	47.382	15.089
Europe	at72106	background	47.271	11.417
Europe	at9stef	background	48.208	16.373
Europe	betr001	background	50.850	4.334
Europe	betr701	background	51.058	3.729
Europe	betr801	background	51.210	4.432
Europe	bg0051a	background	42.143	24.765
Europe	ch0010a	background	47.378	8.530
Europe	ch0011a	background	46.011	8.957
Europe	ch0013a	traffic	47.387	8.540

Europe	ch0031a	traffic	46.951	7.441
Europe	cz0toff	background	49.839	18.264
Europe	cz0ttro	background	49.668	18.678
Europe	cz0umom	background	50.510	13.645
Europe	cz0uulm	background	50.661	14.043
Europe	debb021	background	52.401	13.060
Europe	debe010	background	52.543	13.349
Europe	debw009	background	49.420	8.677
Europe	bg0050a	background	42.681	23.297
Europe	ch0017a	background	47.566	7.582
Europe	cz0mpr	background	49.452	17.454
Europe	debe034	background	52.489	13.431
Europe	debw013	background	48.809	9.230
Europe	debw015	background	49.166	9.225
Europe	debw019	background	48.397	9.979
Europe	debw027	background	48.489	9.207
Europe	debw038	background	47.660	9.486
Europe	debw052	background	47.664	9.169
Europe	debw081	background	49.029	8.356
Europe	debw084	background	48.002	7.832
Europe	deby037	traffic	48.137	11.565
Europe	deby039	background	48.155	11.555
Europe	deby068	background	50.048	10.232
Europe	deby075	background	49.679	12.159
Europe	deby079	background	47.733	12.891
Europe	dehb001	background	53.077	8.816
Europe	dehb004	background	53.181	8.625
Europe	dehe001	background	49.872	8.665
Europe	dehe005	background	50.102	8.543
Europe	dehe008	background	50.125	8.746
Europe	dehe011	background	50.136	8.922
Europe	dehe018	background	50.010	8.452
Europe	dehe022	background	50.050	8.245
Europe	dehe030	background	50.804	8.769
Europe	dehe032	background	50.970	9.800
Europe	dehe045	background	49.673	9.002
Europe	dehh008	background	53.564	9.968
Europe	deni038	background	52.255	8.053

Europe	deni054	background	52.363	9.706
Europe	denw008	background	51.537	7.457
Europe	denw021	industrial	51.526	6.977
Europe	denw038	background	51.453	6.865
Europe	denw042	background	51.338	6.640
Europe	denw067	background	52.023	8.548
Europe	denw071	background	51.249	6.732
Europe	denw094	background	50.755	6.094
Europe	denw095	background	51.937	7.612
Europe	derp019	background	49.446	7.767
Europe	desl003	industrial	49.358	6.734
Europe	desl011	background	49.237	7.036
Europe	desl017	background	49.254	6.868
Europe	desn001	background	50.571	12.997
Europe	desn004	background	51.176	14.444
Europe	desn061	traffic	51.065	13.741
Europe	dest011	background	51.839	10.790
Europe	dest028	background	51.055	12.141
Europe	dest044	background	51.897	11.057
Europe	dest050	background	51.496	11.979
Europe	dest066	background	51.871	12.664
Europe	dest077	background	52.128	11.611
Europe	deth005	background	50.651	11.369
Europe	deth009	background	50.878	12.075
Europe	deth011	background	50.988	12.438
Europe	deth013	background	50.978	10.317
Europe	deth018	background	51.497	10.791
Europe	deth020	background	50.979	11.038
Europe	deth036	background	50.656	12.205
Europe	deth041	background	50.934	11.597
Europe	dk0034a	traffic	55.674	12.571
Europe	dk0046a	background	55.396	10.389
Europe	es0124a	background	40.440	-3.639
Europe	es1072a	industrial	36.159	-5.348
Europe	es1181a	traffic	39.481	-0.447
Europe	es1182a	traffic	38.967	-0.190
Europe	es1185a	traffic	39.667	-0.235
Europe	es1231a	background	41.477	2.089

Europe	es1239a	traffic	39.456	-0.376
Europe	es1353a	background	43.294	-5.680
Europe	es1417a	traffic	42.136	-0.404
Europe	es1421a	background	40.336	-1.107
Europe	es1443a	background	42.336	-3.636
Europe	es1472a	background	42.806	-1.653
Europe	es1490a	industrial	43.168	-2.638
Europe	es1530a	background	43.012	-4.136
Europe	es1537a	background	40.630	-3.172
Europe	fi00425	background	60.187	24.951
Europe	fr01020	background	49.358	6.157
Europe	fr02004	industrial	43.417	5.043
Europe	fr03043	background	43.305	5.395
Europe	fr03080	background	43.950	4.804
Europe	fr04004	background	48.892	2.347
Europe	fr04017	background	48.881	2.278
Europe	fr04037	background	48.829	2.360
Europe	fr04149	background	48.707	2.457
Europe	fr05074	background	49.490	0.101
Europe	fr06003	background	50.378	3.066
Europe	fr06007	background	50.279	3.977
Europe	fr07004	background	45.797	3.114
Europe	fr08016	background	43.592	3.887
Europe	fr08614	background	43.834	4.374
Europe	fr08714	background	42.696	2.901
Europe	fr09003	background	46.163	-1.154
Europe	fr09015	background	46.587	0.359
Europe	fr12004	background	43.576	1.418
Europe	fr12021	background	43.624	1.439
Europe	fr12026	background	43.928	2.146
Europe	fr14033	background	48.295	4.050
Europe	fr15038	background	45.183	5.753
Europe	fr16029	background	48.610	7.782
Europe	fr20017	background	45.735	4.830
Europe	fr21001	background	49.192	-0.391
Europe	fr21019	background	49.152	-0.353
Europe	fr23110	background	47.264	-2.250
Europe	fr25039	background	49.021	1.148

Europe	fr25043	background	49.400	1.099
Europe	fr27002	background	45.368	4.805
Europe	fr29423	background	46.041	4.075
Europe	fr29424	background	45.420	4.395
Europe	fr29426	background	45.475	4.515
Europe	fr31001	background	44.861	-0.579
Europe	fr31002	background	44.801	-0.588
Europe	fr31007	industrial	44.900	-0.515
Europe	fr31013	background	43.311	-0.391
Europe	fr33101	background	45.565	5.928
Europe	fr33102	background	45.597	5.919
Europe	fr33111	background	45.275	6.350
Europe	fr33120	background	45.922	6.870
Europe	fr33121	background	45.675	6.390
Europe	fr33201	background	45.895	6.118
Europe	fr33202	background	45.917	6.136
Europe	fr33211	background	46.196	6.241
Europe	fr35002	background	45.890	0.900
Europe	fr35004	background	45.159	1.537
Europe	fr35005	background	46.170	1.870
Europe	fr35006	background	45.260	1.760
Europe	gb0566a	background	51.522	-0.126
Europe	gb0567a	background	54.600	-5.929
Europe	gb0568a	background	54.978	-1.611
Europe	gb0580a	background	51.482	-3.176
Europe	gb0584a	background	53.804	-1.546
Europe	gb0598a	background	50.908	-1.396
Europe	gb0620a	background	51.521	-0.213
Europe	gb0642a	background	51.496	-0.461
Europe	gb0646a	background	52.955	-1.146
Europe	gb0658a	background	53.028	-2.175
Europe	gb0681a	background	53.563	-1.510
Europe	gb0682a	traffic	51.523	-0.155
Europe	gb0687a	background	50.372	-4.142
Europe	gr0002a	traffic	37.978	23.727
Europe	gr0022a	traffic	38.031	23.787
Europe	gr0032a	traffic	37.999	23.733
Europe	it0732a	background	45.836	8.804

Europe	it0858a	background	44.395	8.992
Europe	it0908a	background	46.470	10.373
Europe	it0953a	background	41.933	12.507
Europe	it0983a	background	45.736	7.324
Europe	it1037a	background	46.063	11.126
Europe	it1110a	background	43.739	10.402
Europe	it1176a	background	41.886	12.542
Europe	it1208a	traffic	42.452	14.198
Europe	it1246a	background	45.569	8.188
Europe	it1423a	background	42.456	14.235
Europe	nl00236	traffic	51.469	5.472
Europe	gr0028a	background	38.021	23.688
Europe	it0448a	background	45.429	12.314
Europe	it0869a	background	41.464	12.913
Europe	it1247a	background	45.559	8.056
Europe	nl00404	background	52.077	4.289
Europe	pl0008a	background	50.265	18.975
Europe	pt03070	background	38.895	-9.117
Europe	pt03071	background	38.769	-9.108
Europe	se0001a	background	55.606	13.002
Europe	se0004a	background	57.709	11.970
Europe	se0022a	background	59.316	18.058
Europe	si0001a	background	46.235	15.262
Europe	si0003a	background	46.066	14.513
Europe	sk0001a	background	48.125	17.125
Europe	sk0037a	background	48.931	21.914
United States of America	1137	urban	29.734	-95.258
United States of America	14442	urban	37.766	-122.399
United States of America	14451	suburban	37.483	-122.203
United States of America	14380	suburban	35.051	-119.403
United States of America	14561	urban	28.596	-81.362
United States of America	14691	suburban	30.041	-90.273
United States of America	14825	urban	35.134	-106.585
United States of America	14995	urban	32.820	-96.860
United States of America	1959	suburban	36.173	-115.333
United States of America	2226	suburban	38.712	-121.381
United States of America	2799	suburban	32.631	-117.059
United States of America	3084	suburban	39.311	-76.474

United States of America	8263	urban	34.051	-118.456
Europe	deby052	background	48.397	10.008
Europe	dehb002	background	53.060	8.917
Europe	dehb005	background	53.562	8.569
Europe	denw053	background	51.019	6.885
Europe	derp022	background	49.841	7.866
Europe	derp025	background	49.052	8.254
Europe	es1047a	traffic	41.651	-0.916
Europe	fr16066	background	47.737	7.309
Europe	fr24009	background	43.558	7.006
Europe	fr30019	background	48.173	6.453
Europe	gb0645a	background	51.477	0.318
Europe	nl00639	traffic	52.068	5.121
Europe	pl0048a	background	54.561	18.493
Europe	sk0020a	background	49.211	18.771

Table S2: Sites not used based on inspection

Region	Station ID	Station Type	Latitude	Longitude
Europe	bg0052a	background	42.667	23.400
Europe	bg0043a	background	43.208	23.557
Europe	bg0013a	background	43.223	27.587