Supplementary materials for

Catalog of NO_x emissions from point sources as derived from the divergence of the NO_2 flux for TROPOMI

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Contents

1 Selection mask

In order to reduce processing time, we define a lat/lon mask for TROPOMI pixels to be processed. This mask is based on a pre-selection of potential stationary sources derived from TROPOMI data.

In a first step, we calculate maps of monthly mean, minimum and maximum NO_2 TVCDs for 2018-2019, including valid (qa>0.75) and cloud free (CF<0.3) observations up to an SZA of 80° on a global lat-lon grid of 0.025° resolution from 61° S to 61° N. Fig. 1(a) displays the annual mean NO_2 TVCD for 2019. Note that due to long range transport or a potential bias in the stratospheric correction, TVCDs might be enhanced for regions without local emissions. In addition, regions exposed to seasonal biomass burning or lightning can show enhanced NO_2 columns that are not caused by stationary point sources. Thus, the mask is not just defined based on an absolute column threshold.

Instead, we define pixels that likely contain stationary sources based on the following three criteria, where thresholds have been derived empirically such that industrial regions are kept while non-stationary sources like biomass burning regions are removed:

1. Sufficient statistic: Monthly means (based on at least 5 valid TROPOMI overpasses) must be available for at least 6 months during the 24 month period 2018-2019.

2. Local maximum: the mean TVCD for 2019 must be enhanced by more than 0.5 $\times 10^{15}$ molec cm^{-2} compared to the local background. This criterion is sensitive for all kind of NO_x sources, including biomass burning.

3. High dynamical range all over the year: The difference between monthly maximum and minimum must exceed 1.5 $\times 10^{15}$ molec cm^{-2} for at least 90% of the available months.
   Due to changing wind patterns, a high dynamical range of TVCDs is expected around stationary sources. For biomass burning, this is only fulfilled during burning season. This criterion thus removes biomass burning regions.

All pixels fulfilling these criteria are considered as candidates for stationary NO_x sources. We now define a mask **M** on 1° resolution, where every grid pixel i, j containing a stationary source candidate is set to $M_{i,j}$=3.

As the further analysis is based on peaks in the divergence map around point sources, also the surrounding of stationary sources should be kept. Thus, the mask values for all neighboring 1° pixels $i \pm 1, j \pm 1$ with $M_{i,j}$=3 are set to 2 (if not set to 3 already), and all pixels with $M_{i,j} \geq 2$ are considered for the calculation of fluxes and divergence. Note that even at 60° N, this corresponds to adding more than 50 km in longitude, which is far more than the 30 km radius considered for peak classification (sect. 3.8).

For all second next neighboring pixels $i \pm 2, j \pm 2$, mask values are set to 1 (if not set to 2 or 3 already). Values $M_{i,j} \geq 1$ are used for the extraction of ECMWF data, which are required for a larger area to enable spatial interpolation later on.

The resulting mask **M** is displayed in Fig. 1(b) and provided as supplementary datafile. Most parts of the continents are kept, except deserts and forests. Open oceans are completely skipped. The application of the mask reduces the amount of pixels included in the further analysis to 13.5% and thereby enables the processing of fluxes on a common desktop computer.

2 Top ten emitters for the USA

We compare the catalog entries and listed emissions exemplarily to the top ten emitters of the USA in 2019 as reported by EPA (Table S1; EPA data from https://ampd.epa.gov/ampd/). Seven out of these ten power plants are listed in the point source catalog, with correct naming derived from the merging of GPPD information. For the 3 missing plants, also a peak in the divergence map is visible (Fig. S1), but the automated algorithm classified these all as “negative”, i.e. a large negative divergence is observed around the plants. As explained in section 3.8.1, this might indicate high noise levels of D or systematic artefacts which might be caused by biased wind fields. Thus, these cases are excluded within the automatized point source identification.

For a discussion of the low biased catalog emissions see section 5.2.6.

Table S1. Top ten NO_x emitters for the USA in 2019 as listed by EPA. Seven of these emitters are listed in the catalog, where a GPPD entry was automatically found matching the name in the EPA list for all cases.

Name	Emissions (EPA) (kg/s)	Emissions (this study) (kg/s)
New Madrid	0.446	0.074
Colstrip	0.432	0.079
Miami Fort	0.360	0.053
Navajo	0.351	0.115
Hunter	0.333	0.040
Scherer	0.319	-
Martin Lake	0.301	-
Fort Martin	0.298	-
Intermountain	0.287	0.054
Thomas Hill	0.285	0.037

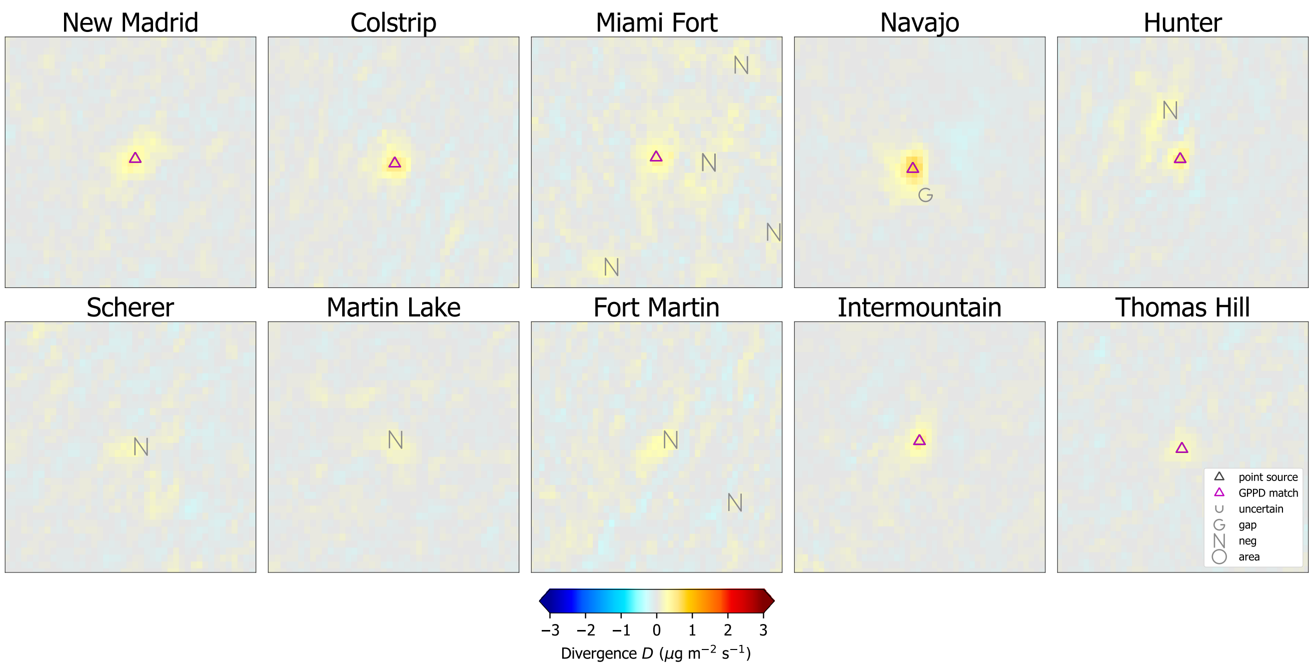

Figure S1. Zooms of the divergence map (100×100 km^2) and candidate classification results for the USA top ten emitters in 2019 as reported by EPA.

3 Regional results

In this section, regional zooms of the divergence map and tables of regional top emitters are provided for all considered regions. The legend for point sources, candidates and the divergence colorbar are the same as in Fig. S1. For sake of clarity, non-pointsources are only shown for candidates with $D_{\max} > 1\mu\mathrm{g\ m^{-2}\ s^{-1}}$ or the integrated divergence within 30 km exceeding $0.1\ \mathrm{kg\ s^{-1}}$. Numbers given in the divergence map refer to the regional ranking as listed in the respective table. For the GPPD matches, fuel and name are only given for the power plant with largest capacity within 5 km.

3.1 North America

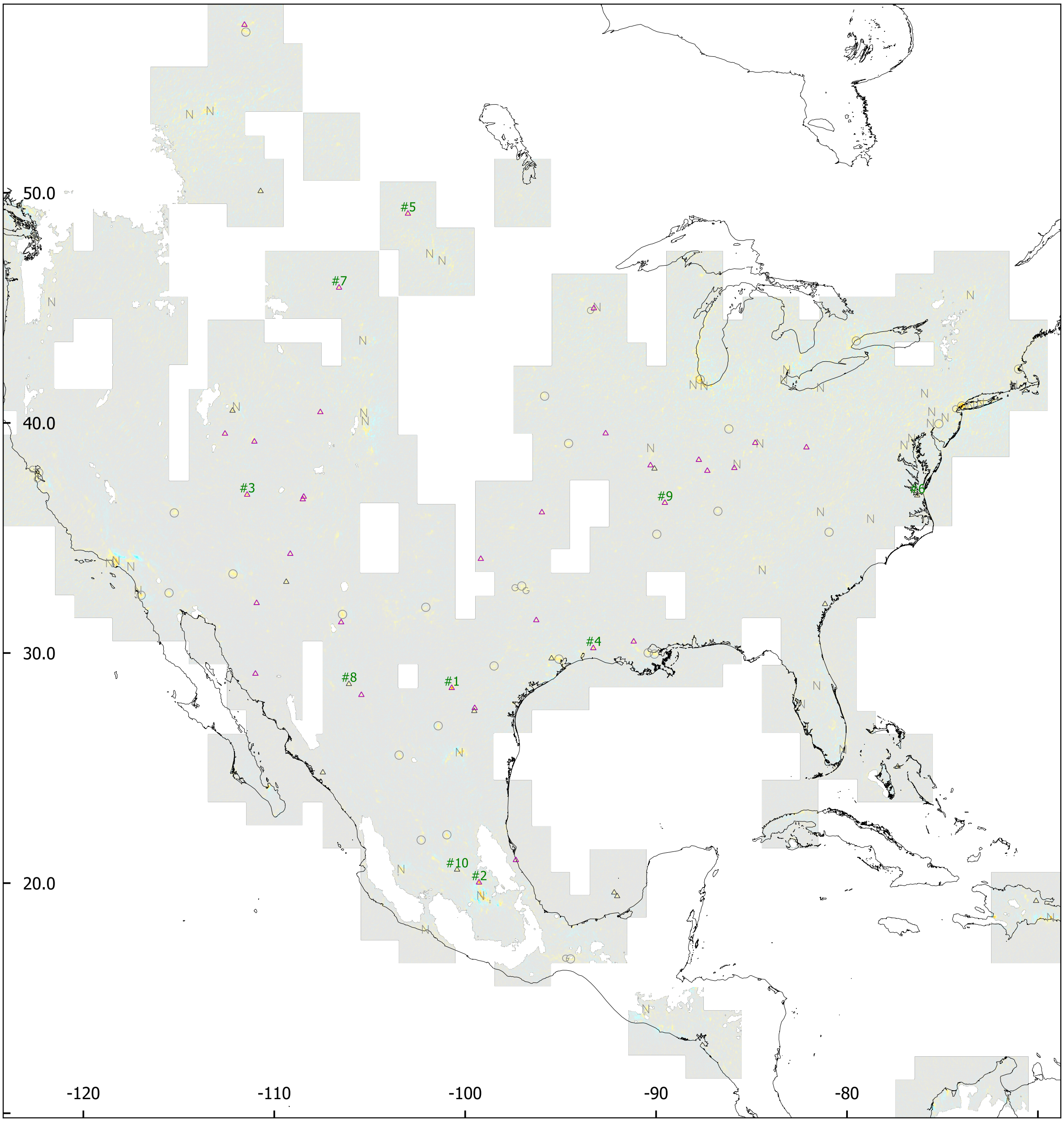

Figure S2. Divergence map and candidate classification results for North America. The regional top ten, as listed in table xy, are marked.

Table S2. Top 10 point sources for North America.

Rank (regional)	Rank (global)	Lat [° N]	Lon [° E]	Emissions [kg/s]	Capacity [GW]	Fuel	Name
1	74	28.481	-100.705	0.175	2.780	Gas	Carbón II
2	91	20.028	-99.276	0.159	2.228	Oil	Francisco Pérez Ríos (Tula)
3	153	36.881	-111.420	0.115	2.409	Coal	Navajo
4	159	30.209	-93.289	0.112	0.851	Gas	RS Cogen
5	184	49.092	-103.000	0.099	0.672	Coal	Boundary Dam
6	236	36.847	-76.324	0.079			
7	237	45.879	-106.608	0.079	2.272	Coal	Colstrip
8	249	28.652	-106.090	0.076			
9	258	36.527	-89.541	0.074	1.300	Coal	New Madrid
10	262	20.585	-100.426	0.073			

3.2 South America

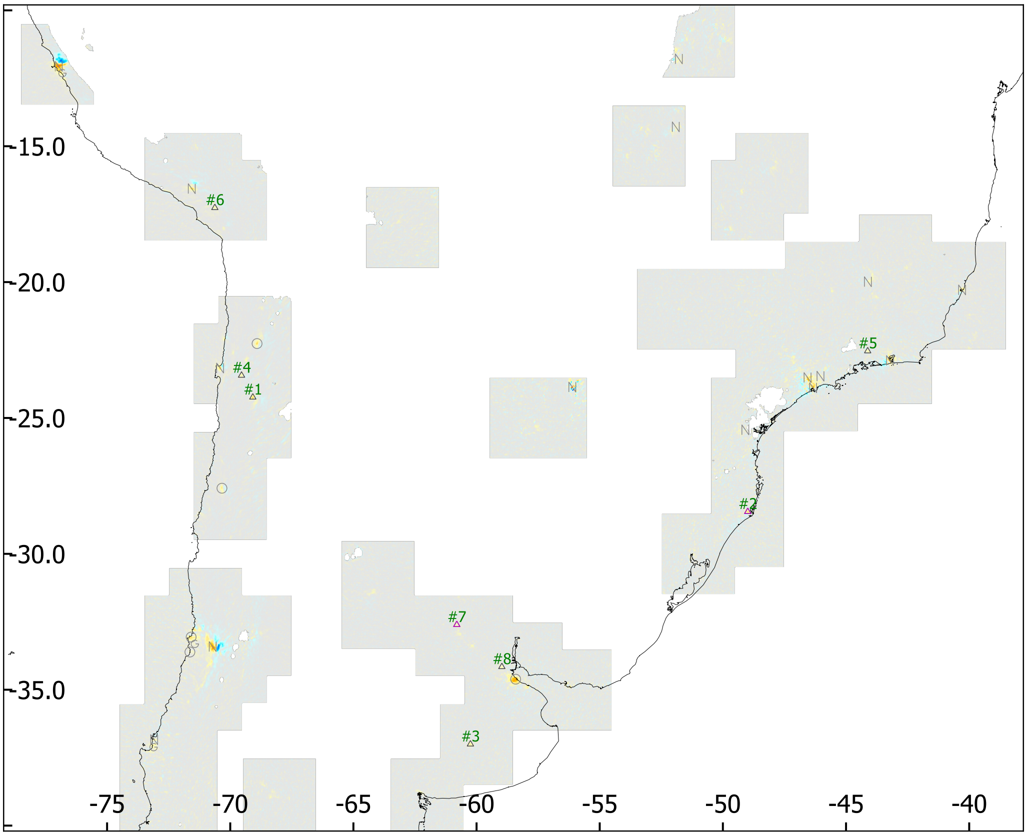

Figure S3. Divergence map and candidate classification results for South America.

Table S3. Point sources for South America.

Rank (regional)	Rank (global)	Lat [° N]	Lon [° E]	Emissions [kg/s]	Capacity [GW]	Fuel	Name
1	157	-24.238	-69.084	0.113			
2	191	-28.449	-48.990	0.095	0.857	Coal	Jorge Lacerda IV
3	238	-37.004	-60.249	0.079			
4	272	-23.434	-69.541	0.069			
5	300	-22.537	-44.121	0.062			
6	412	-17.266	-70.625	0.038			
7	414	-32.610	-60.803	0.038	1.425	Gas	CENTRAL TERMOELECTRICA TIMBUES
8	436	-34.157	-58.973	0.034			

3.3 Europe

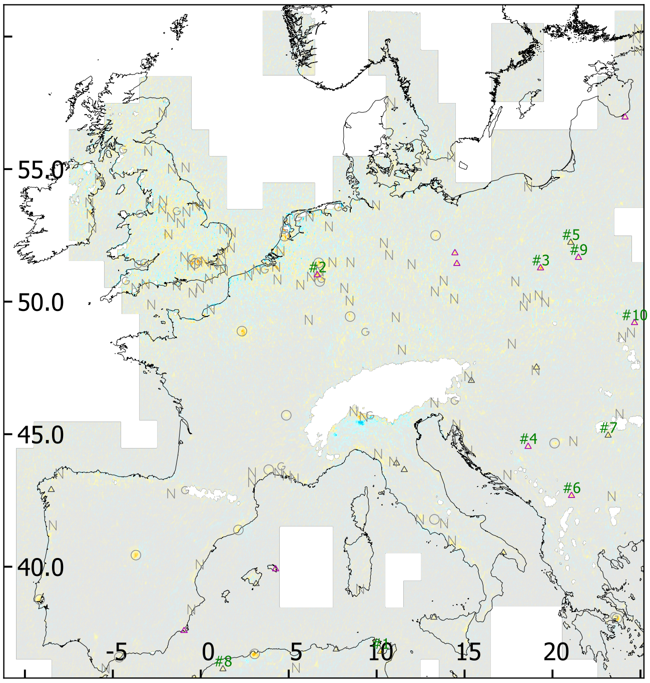

Figure S4. Divergence map and candidate classification results for Europe.

Table S4. Top 10 point sources for Europe. Note that #1 and #8 are in Northern Africa.

Rank (regional)	Rank (global)	Lat [° N]	Lon [° E]	Emissions [kg/s]	Capacity [GW]	Fuel	Name
1	54	36.802	10.224	0.225			
2	87	51.006	6.627	0.163	7.598	Coal	Niederaussem power station
3	110	51.268	19.320	0.148	5.472	Coal	Bełchatów
4	164	44.533	18.614	0.107	0.730	Coal	Tuzla CHP Power Plant Bosnia and Herzegovina
5	179	52.231	21.036	0.101			
6	183	42.681	21.082	0.099	2.713	Coal	Kosovo A Coal Power Plant Kosovo
7	194	44.952	23.163	0.093			
8	240	36.140	1.259	0.078			
9	251	51.664	21.473	0.076	3.748	Coal	Kozienice
10	254	49.200	24.663	0.076	2.334	Coal	Burshtyn power station

3.4 West Africa

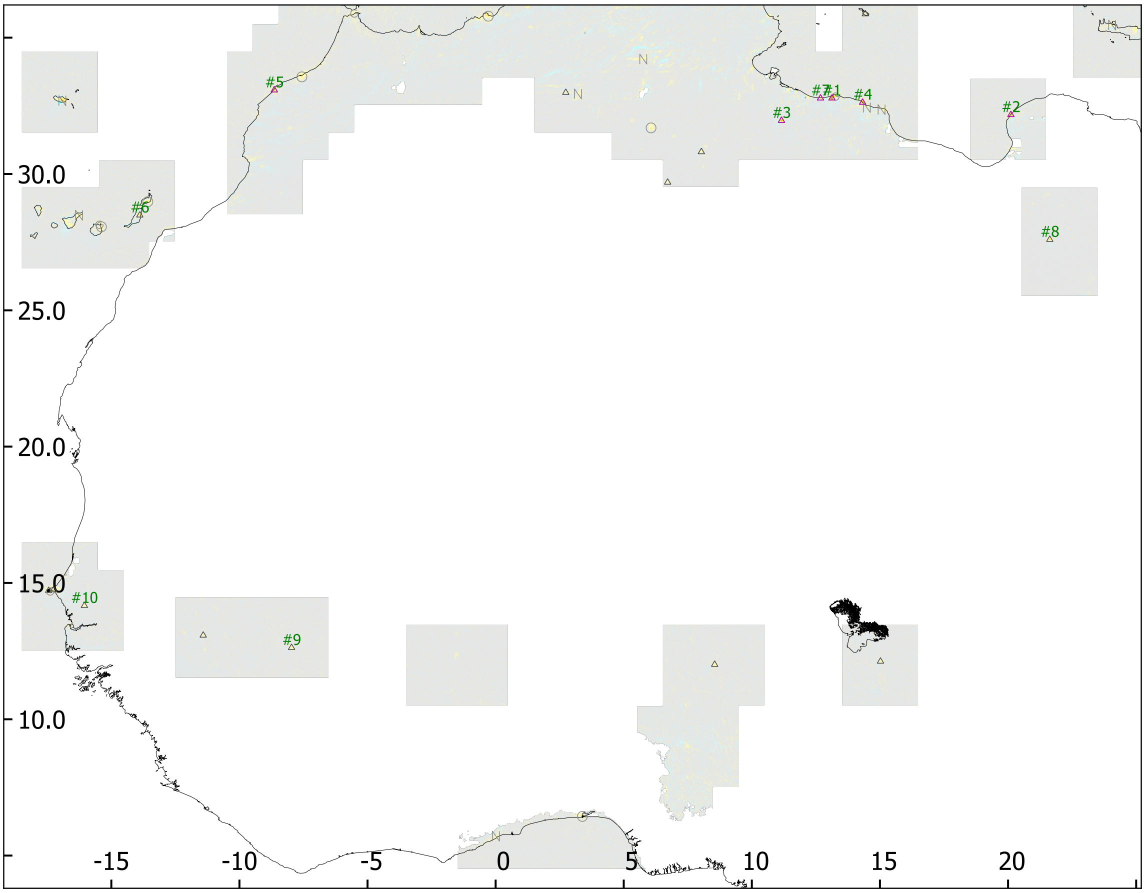

Figure S5. Divergence map and candidate classification results for West Africa. Note that two further point sources in North Africa are listed in the results for Europe due to the coarse definition of regions.

Table S5. Top 10 point sources for West Africa.

Rank (regional)	Rank (global)	Lat [° N]	Lon [° E]	Emissions [kg/s]	Capacity [GW]	Fuel	Name
1	24	32.779	13.126	0.320	0.147	Gas	South Tripoli
2	65	32.171	20.110	0.187	1.040	Gas	North Benghazi Station 1
3	109	31.959	11.156	0.148	0.624	Gas	Western Mountain Station- Ruwais
4	115	32.625	14.323	0.144	1.000	Gas	Al Khums
5	124	33.077	-8.638	0.135	2.020	Coal	Centrale Thermique de Jorf Lasfar (JLEC)
6	156	28.489	-13.888	0.113			
7	176	32.781	12.680	0.102	1.920	Gas	Az Zawiyah
8	193	27.595	21.629	0.094			
9	203	12.626	-7.965	0.091			
10	284	14.168	-16.051	0.066			

3.5 South Africa

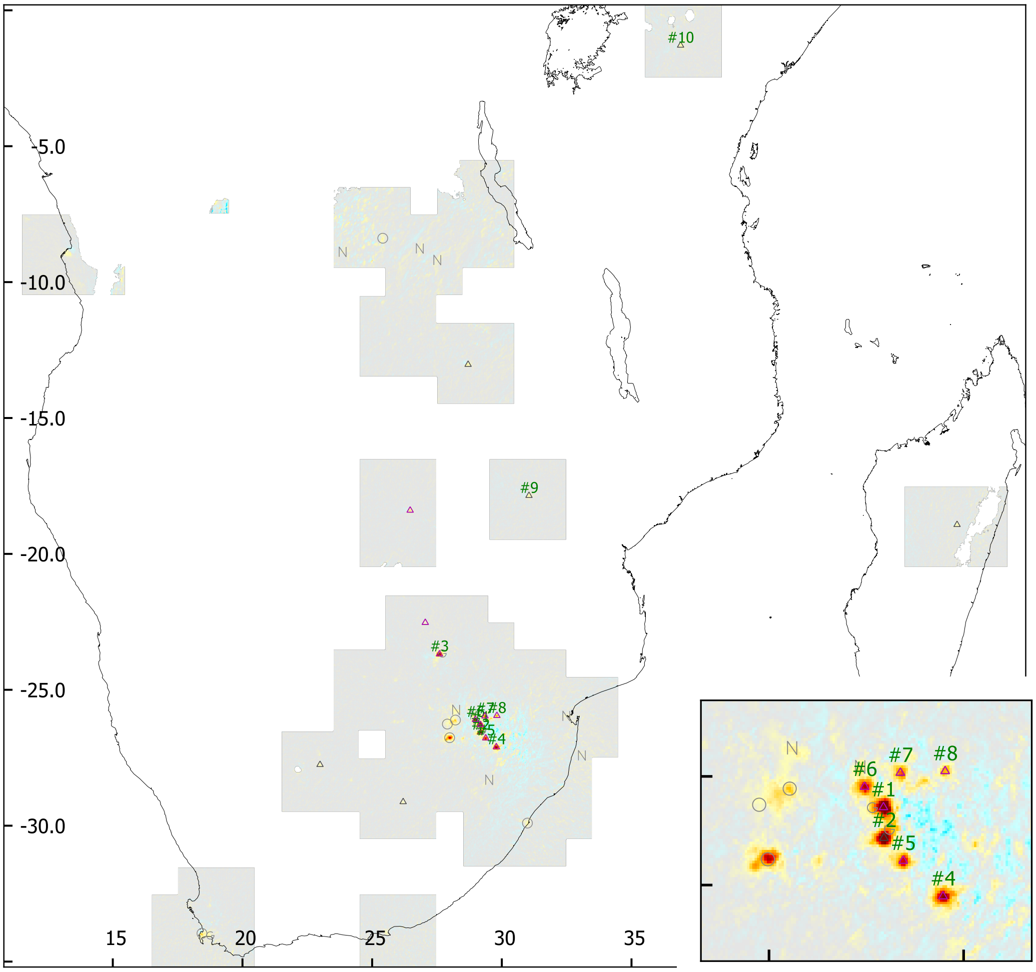

Figure S6. Divergence map and candidate classification results for South Africa, including a zoom for the Highveld with several coal-fired power plants.

Table S6. Top 10 point sources for South Africa.

Rank (regional)	Rank (global)	Lat [° N]	Lon [° E]	Emissions [kg/s]	Capacity [GW]	Fuel	Name
1	1	-26.284	29.176	0.886	6.600	Coal	Matla power station
2	2	-26.566	29.181	0.679			
3	3	-23.686	27.594	0.669	3.990	Coal	Matimba power station
4	4	-27.104	29.788	0.668	4.110	Coal	Majuba power station
5	8	-26.777	29.379	0.474	3.654	Coal	Tutuka power station
6	12	-26.096	28.982	0.437	4.116	Coal	Kendal power station
7	46	-25.967	29.350	0.242	3.600	Coal	Duvha power station
8	84	-25.952	29.810	0.164	2.352	Coal	Arnot power station
9	223	-17.855	31.047	0.082			
10	243	-1.291	36.892	0.077			

3.6 West Russia/East Europe

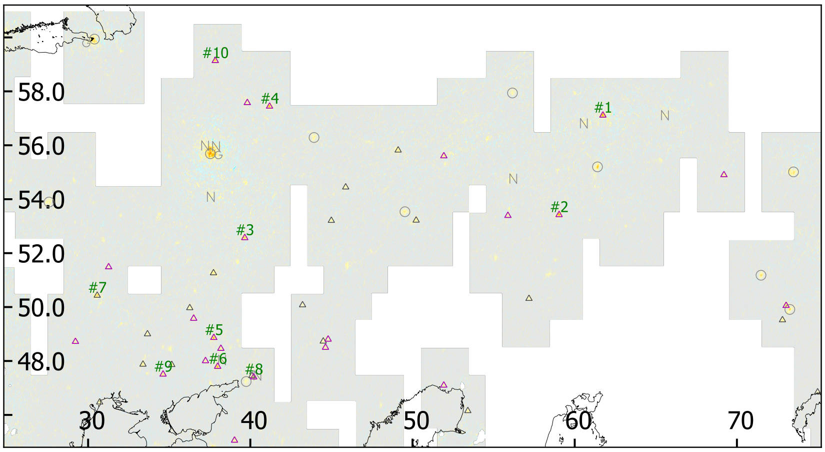

Figure S7. Divergence map and candidate classification results for West Russia/East Europe.

Table S7. Top 10 point sources for West Russia/East Europe.

Rank (regional)	Rank (global)	Lat [° N]	Lon [° E]	Emissions [kg/s]	Capacity [GW]	Fuel	Name
1	51	57.111	61.737	0.232	3.800	Coal	Reftinskaya GRES
2	61	53.422	59.036	0.197	0.330	Coal	CHP Plant of MMK
3	66	52.568	39.657	0.187	0.432	Gas	NLMK cogeneration plant
4	80	57.443	41.187	0.169	3.600	Gas	Krostromskaya
5	81	48.864	37.748	0.169	0.600	Coal	Slavyansk power station
6	86	47.796	37.985	0.163	1.775	Coal	Starobeshivska
7	89	50.431	30.560	0.161			
8	127	47.402	40.208	0.134	2.214	Coal	Novocherkasskaya GRES
9	138	47.506	34.621	0.123	2.825	Coal	Zaporizhia power station
10	141	59.136	37.840	0.122	0.446	Gas	CHP-PVS

3.7 Siberia/Mongolia

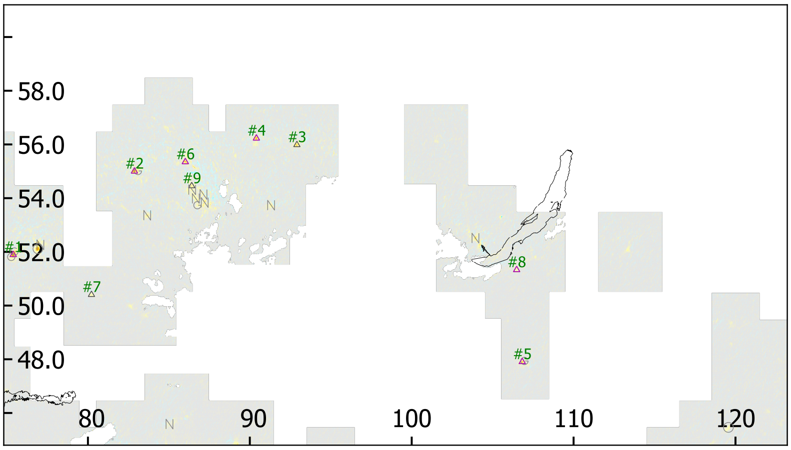

Figure S8. Divergence map and candidate classification results for Siberia/Mongolia.

Table S8. Point sources for Siberia/Mongolia.

Rank (regional)	Rank (global)	Lat [° N]	Lon [° E]	Emissions [kg/s]	Capacity [GW]	Fuel	Name
1	26	51.893	75.386	0.315	4.000	Coal	Ekibastuz-1 power station
2	45	55.000	82.871	0.244	0.852	Coal	Novosibirsk CHP-3
3	118	55.986	92.909	0.140			
4	143	56.229	90.405	0.121	0.320	Coal	CHP of the Achinsk Alumina Combine (TPP AGK)
5	162	47.905	106.827	0.109	0.768	Coal	Ulaanbaatar-4 Thermal Power Plant
6	197	55.350	86.015	0.093	1.050	Coal	NOVO-KEMEROVO CHP
7	247	50.406	80.218	0.076			
8	320	51.330	106.483	0.058	1.160	Coal	Gusinoozyorskaya
9	347	54.455	86.410	0.050			

3.8 Middle East

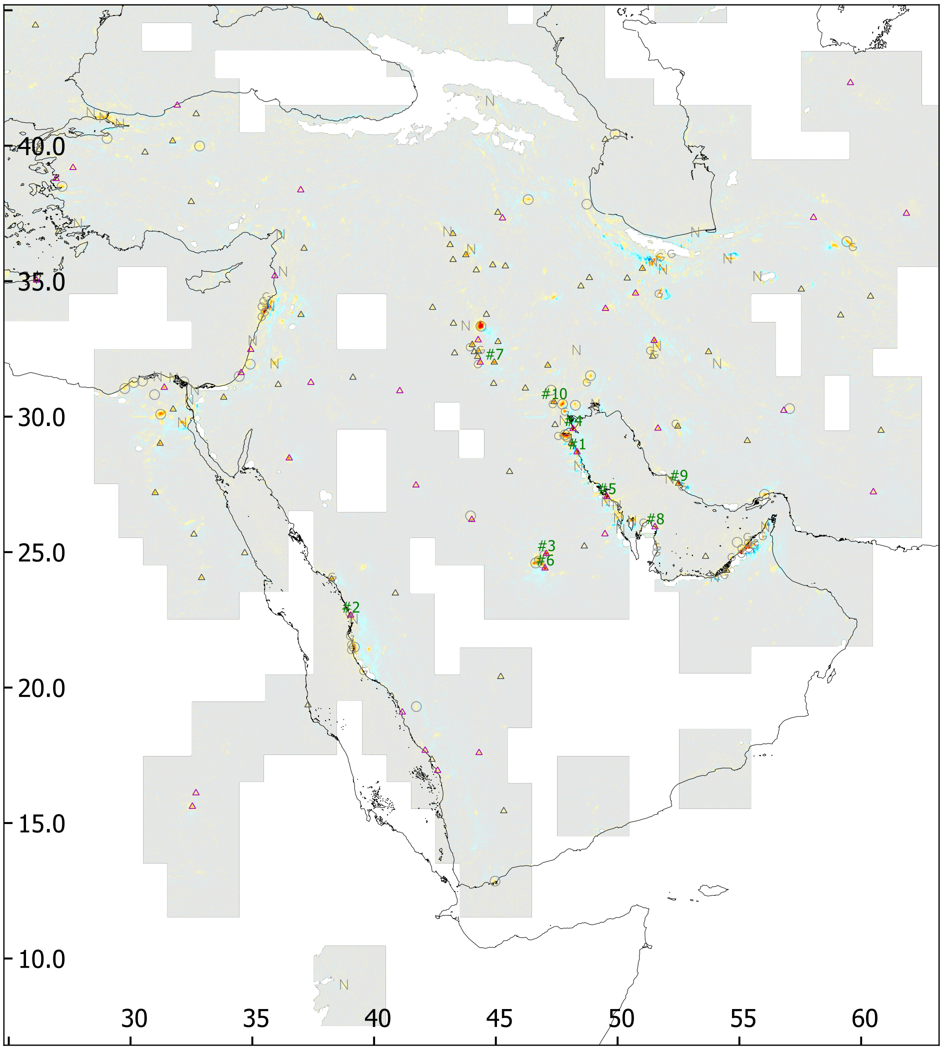

Figure S9. Divergence map and candidate classification results for the Middle East.

Table S9. Top 10 point sources for the Middle East.

Rank (regional)	Rank (global)	Lat [° N]	Lon [° E]	Emissions [kg/s]	Capacity [GW]	Fuel	Name
1	9	28.696	48.334	0.460	6.905	Gas	Az Zour South CCGT
2	11	22.668	39.038	0.438	9.308	Oil	RABIGH
3	13	24.940	47.071	0.428	3.617	Oil	Riyadh 9
4	15	29.551	48.168	0.372	5.367	Gas	Sabiya
5	16	27.044	49.559	0.368	0.250	Gas	JUBAIL COGEN (JEC)
6	19	24.407	47.017	0.347	3.161	Oil	Riyadh 10
7	22	32.007	44.935	0.327			
8	23	25.930	51.535	0.326	4.511	Gas	Ras Laffan C (Ras Qartas) CCGT Power Plant Qatar
9	25	27.533	52.503	0.320			
10	27	30.550	47.386	0.311			

3.9 India/Pakistan/West China

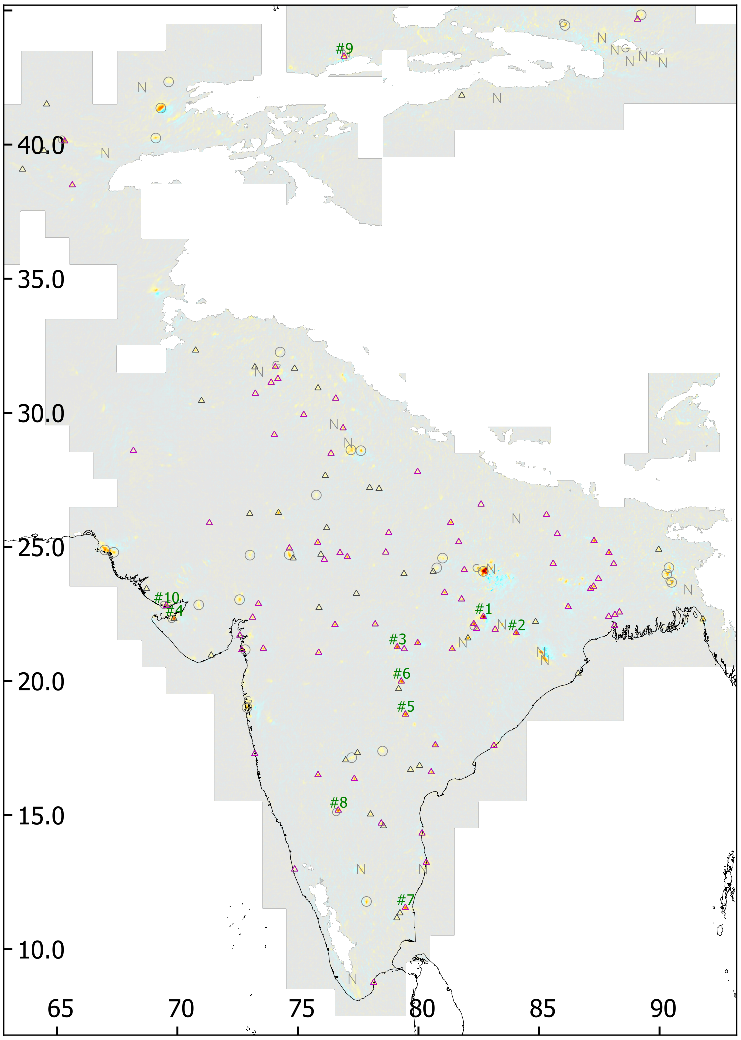

Figure S10. Divergence map and candidate classification results for India/Pakistan/West China.

Table S10. Top 10 point sources for India/Pakistan/West China.

Rank (regional)	Rank (global)	Lat [° N]	Lon [° E]	Emissions [kg/s]	Capacity [GW]	Fuel	Name
1	5	22.397	82.692	0.588	4.830	Coal	KORBA STPS
2	17	21.792	84.055	0.358	0.600	Coal	STERLITE TPP
3	18	21.268	79.120	0.350	3.740	Coal	KORADI
4	20	22.331	69.860	0.328			
5	21	18.759	79.459	0.327	2.600	Coal	R GUNDEM STPS
6	29	19.991	79.285	0.298	2.920	Coal	CHANDRAPUR Coal
7	30	11.550	79.455	0.295	3.240	Coal	NEYVELI ST II
8	31	15.180	76.673	0.292	0.860	Coal	TORANGALLU EXT
9	34	43.290	76.912	0.278	0.145	Coal	Almaty CHP-1
10	37	22.816	69.540	0.272	8.620	Coal	MUNDRA TPP

3.10 East China/South East Asia

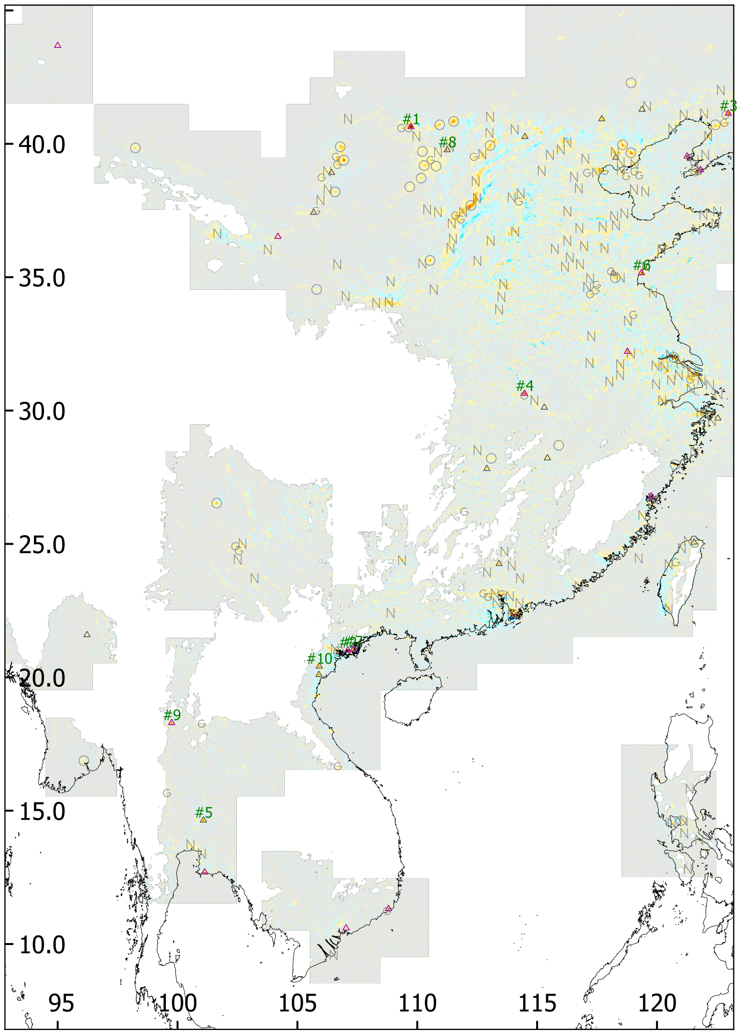

Figure S11. Divergence map and candidate classification results for East China/South East Asia.

Table S11. Top 10 point sources for East China/South East Asia.

Rank (regional)	Rank (global)	Lat [° N]	Lon [° E]	Emissions [kg/s]	Capacity [GW]	Fuel	Name
1	6	40.637	109.739	0.528	0.200	Coal	Baotou Works power station
2	14	21.015	107.107	0.418	1.200	Coal	Quang Ninh 1
3	28	41.137	122.974	0.300	0.345	Coal	Anshan Steel Company No 2 power station
4	42	30.635	114.473	0.257	1.470	Coal	Qingshan power station
5	47	14.638	101.081	0.241			
6	48	35.161	119.352	0.238	0.660	Coal	Rizhao Iron and Steel Cogen power station
7	55	21.060	107.343	0.217	2.200	Coal	Mong Duong 2
8	59	39.770	111.247	0.202			
9	60	18.294	99.756	0.202	2.400	Coal	Mae Mah
10	62	20.409	105.911	0.197			

3.11 East Asia

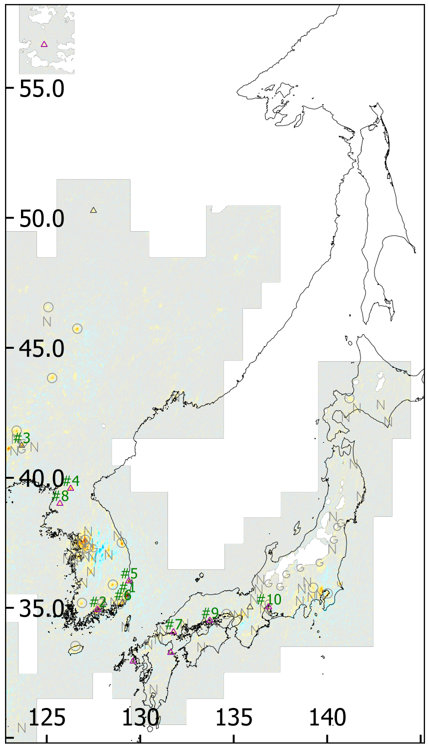

Figure S12. Divergence map and candidate classification results for East Asia.

Table S12. Top 10 point sources for East Asia.

Rank (regional)	Rank (global)	Lat [° N]	Lon [° E]	Emissions [kg/s]	Capacity [GW]	Fuel	Name
1	7	35.502	129.303	0.523			
2	10	34.930	127.723	0.460	1.330	Gas	Gwangyang Works
3	41	41.239	123.654	0.258			
4	79	39.586	126.277	0.171	1.600	Coal	Pukchang power station
5	103	36.028	129.390	0.150	0.491	Gas	Pohang Works
6	120	35.197	129.053	0.137			
7	168	34.068	131.780	0.105	0.481	Coal	Nanyo Complex power station
8	181	39.010	125.704	0.100	0.900	Coal	East Pyongyang power station
9	190	34.509	133.722	0.096	1.312	Oil	Tamashima
10	224	35.030	136.871	0.082	6.325	Oil	Shin Nagoya

3.12 Indonesia/Malaysia

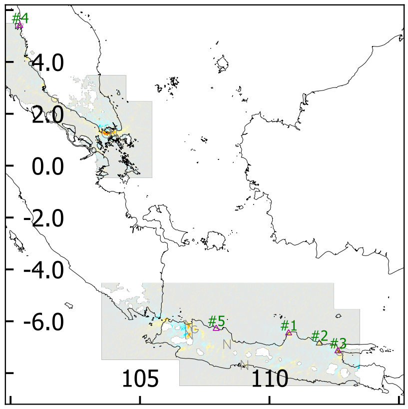

Figure S13. Divergence map and candidate classification results for Indonesia/Malaysia.

Table S13. Point sources for Indonesia/Malaysia.

Rank (regional)	Rank (global)	Lat [° N]	Lon [° E]	Emissions [kg/s]	Capacity [GW]	Fuel	Name
1	111	-6.458	110.741	0.146	2.644	Coal	PLTU Tanjung Jati B - expansion
2	112	-6.852	111.921	0.146			
3	114	-7.148	112.643	0.145	2.179	Gas	PLTGU Gresik
4	318	5.396	100.356	0.058	1.751	Gas	TNB Prai
5	440	-6.284	107.942	0.033	0.990	Coal	PLTU Jawa Barat - Indramayu

3.13 Australia/New Zealand

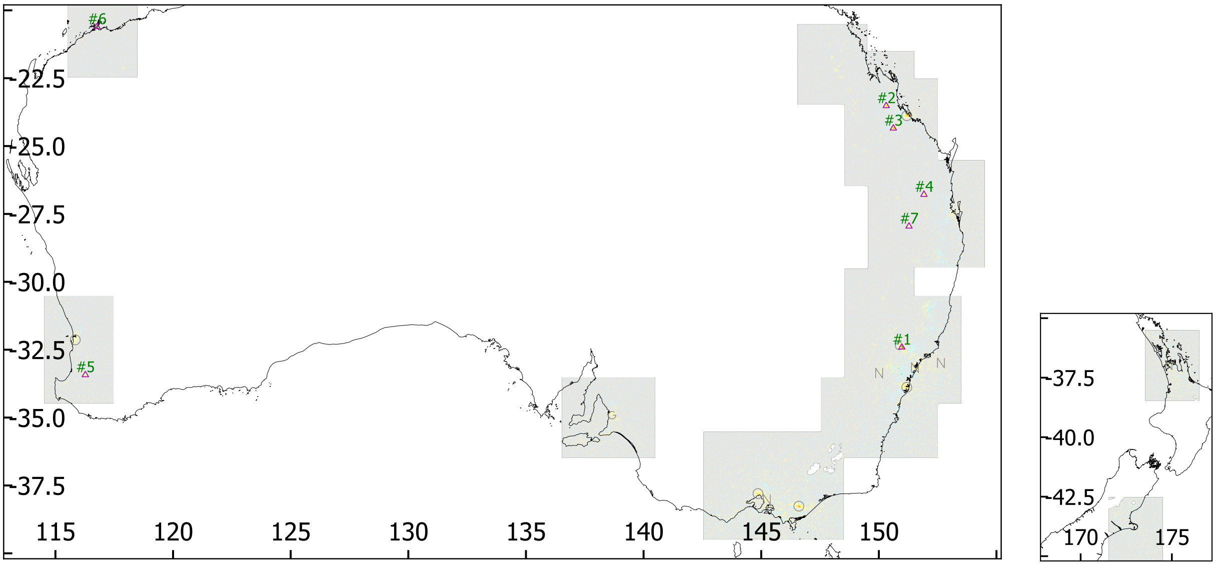

Figure S14. Divergence map and candidate classification results for Australia (left) and New Zealand (right).

Table S14. Point sources for Australia.

Rank (regional)	Rank (global)	Lat [° N]	Lon [° E]	Emissions [kg/s]	Capacity [GW]	Fuel	Name
1	35	-32.412	150.977	0.276	4.840	Coal	Bayswater
2	96	-23.519	150.314	0.155	1.460	Coal	Stanwell
3	98	-24.346	150.615	0.152	1.540	Coal	Callide C
4	196	-26.785	151.917	0.093	1.843	Coal	Tarong
5	252	-33.428	116.270	0.076	1.094	Coal	Muja D
6	369	-20.608	116.771	0.045	0.400	Gas	Burrup Peninsula (Karratha Gas Plant)
7	371	-27.955	151.282	0.045	0.856	Coal	Millmerran

4 Comparison between NO_x emissions and power plant capacity

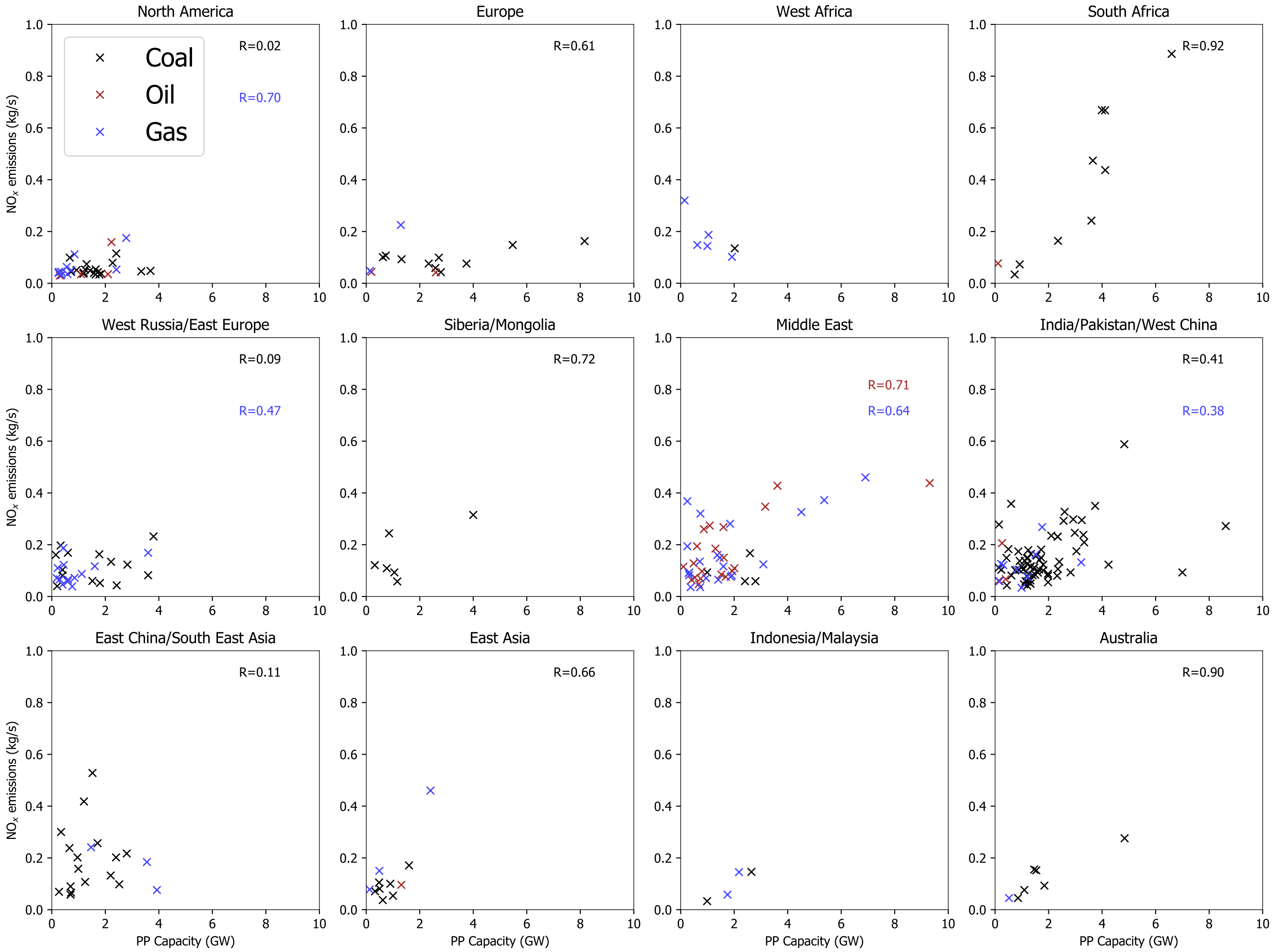

Figure S15. Correlation between point source emissions and power plant capacity for the considered regions, except New Zealand (no point source found) and South America (8 point sources/2 power plants). Correlation coefficients are displayed if more than 5 data points are available.