Supporting Information for:

Post-Dieselgate: evidence of NO_x emission reductions using on-road remote sensing

Stuart K. Grange,[*,†,‡] Naomi J. Farren,[‡] Adam R. Vaughan,[‡] Jack Davison,[‡] and David C. Carslaw[*,‡]

†*Empa, Swiss Federal Laboratories for Materials Science and Technology, Überlandstrasse 129, 8600 Dübendorf, Switzerland*

‡*Wolfson Atmospheric Chemistry Laboratories, University of York, York, YO10 5DD, United Kingdom*

E-mail: stuart.grange@empa.ch; david.carslaw@york.ac.uk

Number of pages: 9

Number of tables: 4

Number of figures: 4

Supporting Information Available

The following files are available free of charge.

Tables

Table SI 1 Basic information for the ten locations, sites, or roads where on-road remote sensing was conducted.

Table SI 2 The 44 vehicle families which were used in the analysis and the number of NO_x measurements used for data analysis.

Table SI 3 The manufacturer groups which were included in the analysis along with their makes or marques.

Table SI 4 Descriptive statistics for on-road NO_x emissions for 44 manufacturer groups' light-duty Euro 5 diesel vehicles for pre- and post-Dieselgate time periods.

Figures

Figure SI 1 The three regions in England, United Kingdom (UK) where on-road remote sensing was undertaken.

Figure SI 2 Timeline and locations of when on-road remote sensing was undertaken.

Figure SI 3 Air temperature distributions when on-road remote sensing monitoring was undertaken for two time periods.

Figure SI 4 Generalized additive models (GAMs) predicting NO_x emissions based on air temperature for 26 vehicle families.

Table SI 1: Basic information for the ten locations, sites, or roads where on-road remote sensing was conducted.

Site name	Lat.	Long.	Elevation (m)	Region	Road name	Road ref.	Road type
Greenford Road	51.5	-0.4	6	London	Greenford Road	A4127	Primary
West End Road	51.6	-0.4	47	London	West End Road	A4180	Primary
Putney Hill	51.5	-0.2	37	London	Putney Hill	A219	Primary
Northolt A40 slip road	51.5	-0.4	47	London	Western Avenue	A40	Trunk
Aldersgate Street	51.5	-0.1	17	London	Aldersgate Street	A1	Primary
Queen Victoria Street	51.5	-0.1	20	London	Queen Victoria Street		Tertiary
Oxpens Road	51.7	-1.3	57	Oxford	Oxpens Road	A420	Primary
Oxford High Street	51.8	-1.3	63	Oxford	High Street	A420	Tertiary
University of York University Road	53.9	-1.1	26	York	University Road		Tertiary
Poppleton Roundabout	54.0	-1.1	21	York	Ring Road	A59	Trunk

Table SI 2: The 44 vehicle families which were used in the analysis and the number of NO_x measurements used for data analysis. For the makes which compose the manufacturer groups, see Table SI 3 and TAC is the abbreviation for type approval category.

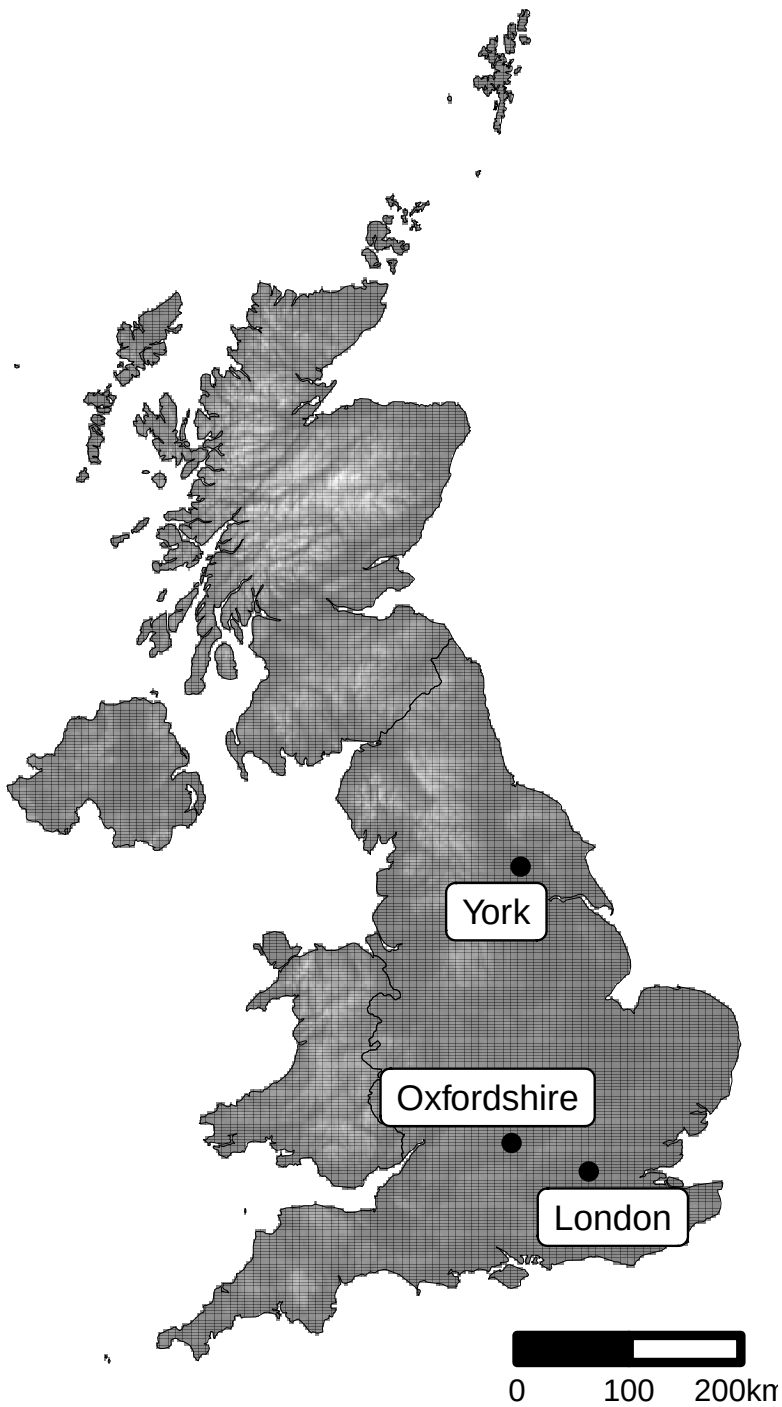
TAC	Vehicle family	n	TAC Euro 5 share (%)
M1	Daimler AG 2.1 L M1	1948	14.4
M1	VWG 2.0 L M1	1765	13.0
M1	Ford 2.0 L M1	1476	10.9
M1	BMW 2.0 L M1	1131	8.3
M1	VWG 1.6 L M1	1038	7.6
M1	Tata 3.0 L M1	725	5.3
M1	Daimler AG 3.0 L M1	557	4.1
M1	BMW 3.0 L M1	539	4.0
M1	PSA 1.6 L M1	521	3.8
M1	GM 2.0 L M1	500	3.7
M1	Tata 2.2 L M1	417	3.1
M1	VWG 3.0 L M1	400	2.9
M1	Ford 1.6 L M1	380	2.8
M1	RNA 1.5 L M1	302	2.2
M1	LTI 2.5 L M1	288	2.1
M1	Volvo 2.4 L M1	269	2.0
M1	GM 1.7 L M1	218	1.6
M1	Volvo 2.0 L M1	187	1.4
M1	Hyundai 1.6 L M1	148	1.1
M1	BMW 1.6 L M1	129	1.0
M1	Tata 4.4 L M1	129	1.0
M1	Hyundai 1.7 L M1	107	0.8
M1	PSA 2.0 L M1	96	0.7
M1	Volvo 1.6 L M1	79	0.6
M1	Honda 2.2 L M1	80	0.6
M1	Hyundai 2.2 L M1	76	0.6
M1	Toyota 2.0 L M1	65	0.5
N1	Ford 2.2 L N1	1387	20.4
N1	Daimler AG 2.1 L N1	1380	20.3
N1	VWG 2.0 L N1	864	12.7
N1	PSA 1.6 L N1	774	11.4
N1	VWG 1.6 L N1	415	6.1
N1	GM 2.0 L N1	339	5.0
N1	PSA 2.2 L N1	241	3.5
N1	RNA 2.0 L N1	234	3.4
N1	RNA 2.3 L N1	211	3.1
N1	RNA 1.5 L N1	211	3.1
N1	FCA 2.3 L N1	184	2.7
N1	Ford 1.6 L N1	163	2.4
N1	PSA 1.2 L N1	126	1.9
N1	GM 1.2 L N1	109	1.6
N1	RNA 2.5 L N1	86	1.3
N1	FCA 1.2 L N1	80	1.2

Table SI 3: The manufacturer groups which were included in the analysis along with their makes or marques.

Manufacturer group	Makes or marques
BMW	BMW, Mini
Daimler AG	Mercedes, Mercedes-Benz
FCA	Iveco, Fiat
Ford	Ford
GM	Vauxhall, Chevrolet
Honda	Honda
Hyundai	Kia, Hyundai
LTI	London Taxis Int
PSA	Citroen, Peugeot
RNA	Renault, Nissan, Dacia
Tata	Jaguar, Land Rover
Toyota	Toyota
Volvo	Volvo
VWG	Volkswagen, Audi, Seat, Skoda, Porsche

Table SI 4: Descriptive statistics for on-road NO_x emissions for 44 manufacturer groups' light-duty Euro 5 diesel vehicles for pre- and post-Dieselgate time periods. The summaries are ordered by type approval category (TAC) and mean change. The ranges represent 95 % confidence intervals.

TAC	Man. group	Engine size (L)	Pre-Dieselgate ($g\,kg^{-1}$)	Post-Dieselgate ($g\,kg^{-1}$)	Delta ($g\,kg^{-1}$)	Change (%)
M1	VWG	1.6 L	24.9 [23.9, 25.9]; $n = 591$	15.9 [14.8, 17.0]; $n = 437$	-9.0	-36.2
M1	VWG	2.0 L	17.0 [16.3, 17.7]; $n = 982$	13.3 [12.5, 14.1]; $n = 772$	-3.7	-21.8
M1	Ford	1.6 L	18.3 [16.7, 20.0]; $n = 233$	14.9 [13.1, 16.7]; $n = 144$	-3.4	-18.7
M1	Hyundai	2.2 L	26.6 [18.8, 34.3]; $n = 40$	23.2 [16.8, 29.6]; $n = 35$	-3.4	-12.8
M1	Daimler AG	3.0 L	13.6 [12.8, 14.5]; $n = 472$	10.3 [8.8, 11.9]; $n = 83$	-3.3	-24.1
M1	Hyundai	1.7 L	23.0 [17.8, 28.2]; $n = 30$	21.0 [17.7, 24.2]; $n = 76$	-2.0	-8.8
M1	Ford	2.0 L	17.2 [16.6, 17.8]; $n = 1168$	15.4 [14.2, 16.6]; $n = 297$	-1.8	-10.3
M1	Daimler AG	2.1 L	17.9 [17.3, 18.5]; $n = 1456$	16.5 [15.4, 17.6]; $n = 478$	-1.4	-7.6
M1	PSA	1.6 L	16.5 [15.1, 17.9]; $n = 246$	16.0 [14.7, 17.4]; $n = 271$	-0.5	-3.0
M1	BMW	3.0 L	9.3 [8.7, 9.9]; $n = 390$	8.8 [7.6, 10.1]; $n = 144$	-0.4	-4.8
M1	BMW	1.6 L	12.2 [10.1, 14.3]; $n = 80$	12.1 [9.7, 14.4]; $n = 47$	-0.2	-1.2
M1	BMW	2.0 L	13.1 [12.4, 13.9]; $n = 694$	13.1 [12.2, 14.1]; $n = 422$	0.0	0.1
M1	PSA	2.0 L	13.0 [9.7, 16.3]; $n = 53$	13.5 [10.9, 16.1]; $n = 42$	0.5	3.7
M1	Volvo	1.6 L	23.0 [19.5, 26.5]; $n = 48$	23.5 [16.7, 30.3]; $n = 31$	0.5	2.2
M1	Volvo	2.4 L	11.5 [10.2, 12.8]; $n = 154$	12.1 [10.9, 13.3]; $n = 113$	0.6	5.3
M1	Volvo	2.0 L	11.5 [9.8, 13.1]; $n = 128$	12.9 [10.6, 15.1]; $n = 58$	1.4	12.5
M1	Tata	3.0 L	13.8 [12.7, 14.9]; $n = 438$	16.1 [14.9, 17.2]; $n = 283$	2.3	16.4
M1	Tata	2.2 L	12.5 [11.4, 13.7]; $n = 166$	15.3 [14.3, 16.3]; $n = 250$	2.8	22.3
M1	RNA	1.5 L	21.8 [19.4, 24.3]; $n = 149$	24.9 [22.4, 27.4]; $n = 151$	3.1	14.0
M1	Tata	4.4 L	9.0 [6.8, 11.2]; $n = 68$	13.1 [10.3, 15.9]; $n = 59$	4.1	45.3
M1	Honda	2.2 L	16.6 [13.3, 20.0]; $n = 42$	20.8 [15.4, 26.2]; $n = 37$	4.2	25.0
M1	Toyota	2.0 L	14.7 [11.1, 18.4]; $n = 31$	18.9 [14.4, 23.4]; $n = 33$	4.2	28.5
M1	GM	1.7 L	17.3 [15.2, 19.4]; $n = 139$	21.6 [18.9, 24.4]; $n = 75$	4.3	24.6
M1	Hyundai	1.6 L	15.2 [12.3, 18.2]; $n = 83$	20.9 [17.7, 24.1]; $n = 64$	5.7	37.1
M1	VWG	3.0 L	16.5 [14.8, 18.1]; $n = 259$	25.6 [23.0, 28.1]; $n = 139$	9.1	55.1
M1	LTI	2.5 L	26.8 [24.6, 28.9]; $n = 212$	36.4 [33.9, 38.9]; $n = 75$	9.6	36.0
M1	GM	2.0 L	16.1 [14.7, 17.6]; $n = 305$	31.2 [28.7, 33.7]; $n = 191$	15.0	93.2
N1	VWG	1.6 L	26.1 [24.7, 27.4]; $n = 252$	20.2 [18.4, 22.0]; $n = 160$	-5.9	-22.5
N1	PSA	1.2 L	26.5 [23.1, 30.0]; $n = 89$	21.9 [18.6, 25.3]; $n = 34$	-4.6	-17.2
N1	FCA	1.2 L	21.1 [17.2, 24.9]; $n = 42$	16.9 [14.5, 19.3]; $n = 38$	-4.2	-19.8
N1	Ford	1.6 L	17.0 [13.6, 20.3]; $n = 50$	15.1 [13.0, 17.2]; $n = 113$	-1.9	-10.9
N1	PSA	2.2 L	13.0 [11.4, 14.6]; $n = 79$	13.8 [12.4, 15.2]; $n = 157$	0.8	6.0
N1	Daimler AG	2.1 L	26.5 [25.6, 27.3]; $n = 879$	27.8 [26.7, 29.0]; $n = 494$	1.4	5.2
N1	PSA	1.6 L	16.7 [15.4, 17.9]; $n = 374$	19.2 [18.0, 20.4]; $n = 392$	2.5	15.2
N1	RNA	2.5 L	17.5 [14.4, 20.6]; $n = 44$	20.1 [16.2, 24.0]; $n = 40$	2.6	15.0
N1	Ford	2.2 L	16.4 [15.3, 17.4]; $n = 514$	19.7 [18.8, 20.7]; $n = 860$	3.4	20.7
N1	GM	2.0 L	21.0 [19.0, 23.0]; $n = 200$	27.4 [24.7, 30.1]; $n = 133$	6.4	30.4
N1	GM	1.2 L	15.3 [12.7, 17.9]; $n = 48$	23.6 [19.4, 27.7]; $n = 60$	8.3	54.1
N1	VWG	2.0 L	17.2 [16.1, 18.4]; $n = 496$	26.4 [24.9, 27.9]; $n = 363$	9.2	53.1
N1	RNA	2.0 L	23.4 [21.0, 25.7]; $n = 132$	33.3 [30.5, 36.2]; $n = 98$	10.0	42.7
N1	RNA	2.3 L	24.3 [21.2, 27.5]; $n = 117$	38.3 [34.1, 42.6]; $n = 92$	14.0	57.6
N1	RNA	1.5 L	15.8 [14.0, 17.6]; $n = 109$	31.8 [27.7, 35.9]; $n = 100$	16.0	101.4
N1	FCA	2.3 L	18.7 [16.4, 20.9]; $n = 109$	37.6 [32.7, 42.6]; $n = 73$	19.0	101.4



Polygons: Made with Natural Earth
Elevation: Shuttle Radar Topography Mission (SRTM)

Figure SI 1: The three regions in England, United Kingdom (UK) where on-road remote sensing was undertaken. Within these regions, 10 locations were used as monitoring sites (Table SI 1; Figure SI 2). The fill-colour represents the terrain's elevation.

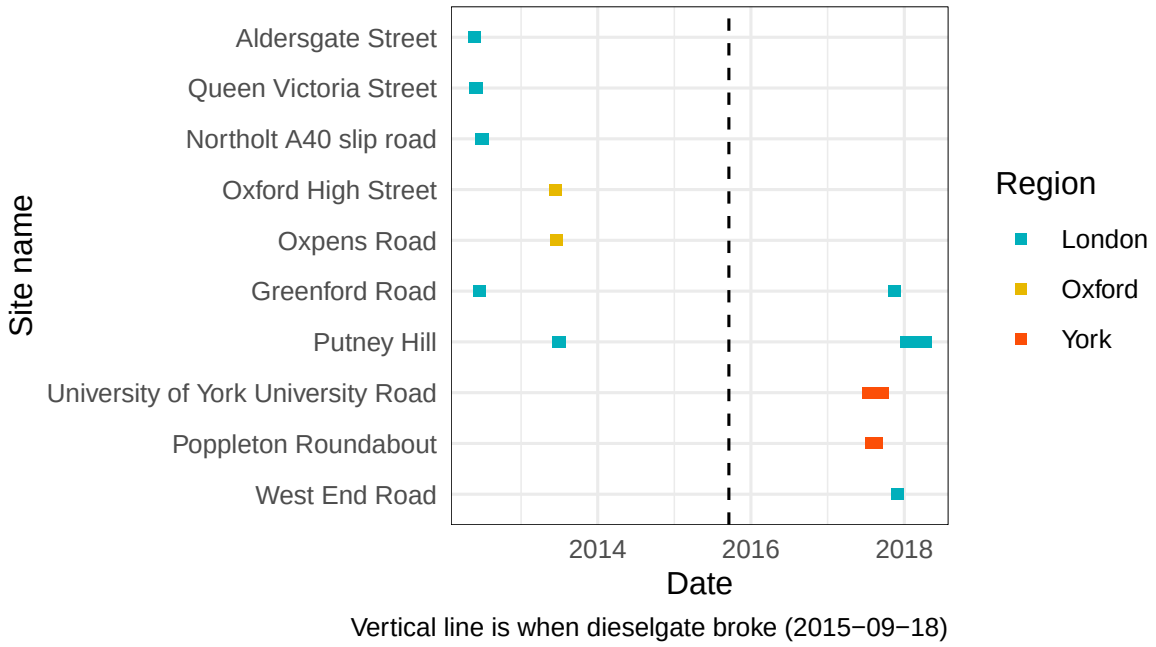


Figure SI 2: Timeline and locations of when on-road remote sensing was undertaken.

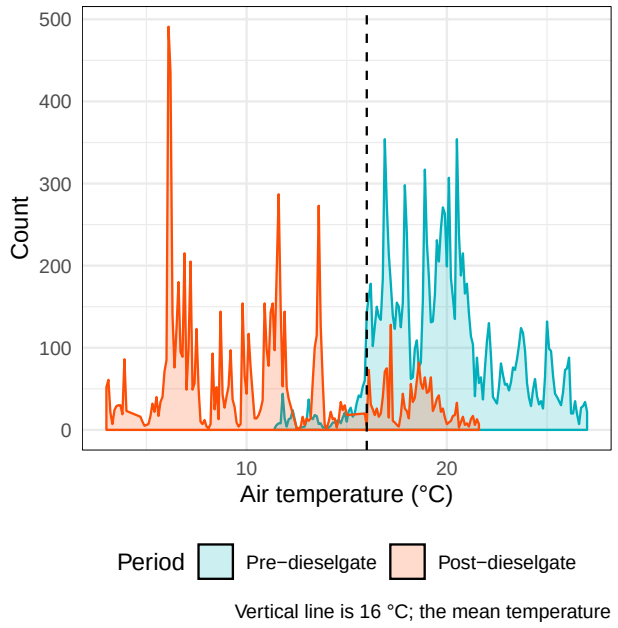


Figure SI 3: Air temperature distributions when on-road remote sensing monitoring was undertaken for two time periods.

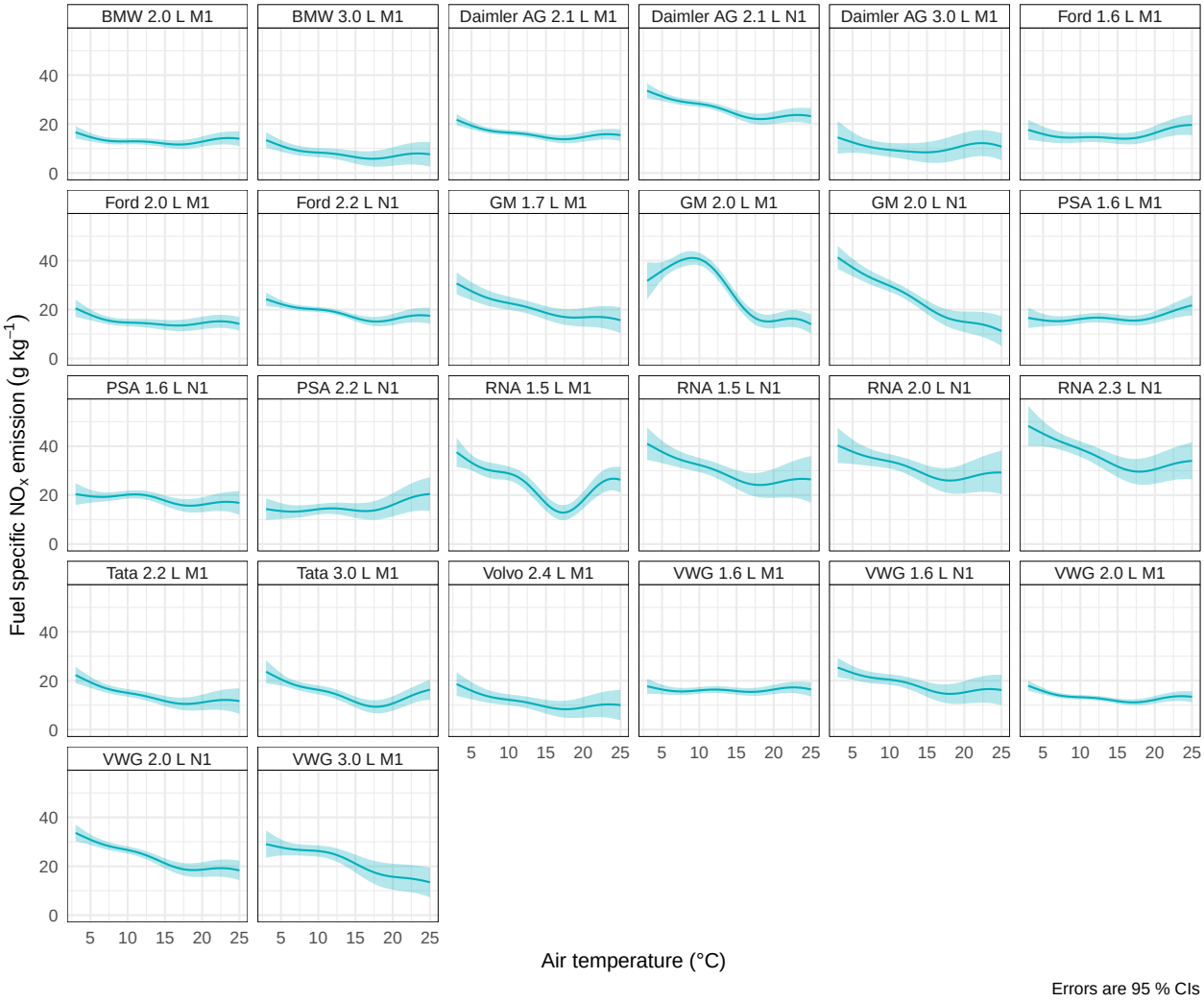


Figure SI 4: Generalized additive models (GAMs) predicting NO_x emissions based on air temperature for 26 vehicle families ($n \geq 200$).