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Measurement report: In-depth characterization of ship emissions during operations in a Mediterranean port

Lise Le Berre et al.

Correspondence to: Lise Le Berre (lise.le-berre@univ-amu.fr) and Brice Temime-Roussel (brice.temime-roussel@univ-amu.fr)

Figures

Tables

Table S1. Specifications of the instruments used during the campaign. The term n/a means not applicable.

	Measured Quantity	Instrument	Size Range	Temporal resolution	Flow ($L.min^{-1}$)	Detection Limit	Uncertainty
PARTICULATE PHASE	**Particle number (PN)** Particle number concentration (PNC)	CPC TSI 3776 (TSI, Germany)	2.5 nm – 3 µm(1)	1 s	1.5	n/a	±10%
		Envi CPC 200 (PALAS, Germany)	7 nm – 2.5 µm(1)	1 s	0.9	n/a	±5%
	Particle size distribution Particle number concentration (PNC)	SMPS 3936 (CPC 3775 - Classifier 3080 - Long DMA) (TSI, Germany)	15 nm – 660 nm(2)	2 min	0.3	n/a	$\pm\sqrt{N}/N$(4)
		SMPS 3936 (CPC 3776 - Classifier 3080 - Long DMA) (TSI, Germany)	15 nm – 660 nm(2)	2 min	0.3	n/a	$\pm\sqrt{N}/N$(4)
	Particle size distribution Particle number and mass concentration	OPC model 1.109 (Grimm Aerosol Technik, Germany)	0.25 µm – 32 µm(3)	1 min	1.2	n/a	±2%
	Black Carbon (BC) Particle mass concentration	MAAP 5012 (ThermoFisher, USA)	< 1 µm(1)	1 min	16,7	0.3 $\mu g.m^{-3}$	±10%
		AE33 (Aerosol Magee Scientific, USA)	< 1 µm(1)	1 min	5	0.3 $\mu g.m^{-3}$	±10%
	Non refractory chemical composition Particle mass concentration	HR-ToF-AMS (Aerodyne, USA)	30 nm – 600 nm(1)	30 s	0.08	0.005 - 0.05(5) $\mu g.m^{-3}$	±30%
	Metals composition Particle mass concentration	Xact 625i (Cooper Environment, USA)	< 1 µm(1)	30 min	16.7	0.1 - 50(5) $ng.m^{-3}$	-(6)
GAS PHASE	**Volatils Organic Compounds (VOC)** Gazeous concentration	PTR-ToF-MS 8000 (Ionicon Analytik, Austria)	n/a	10 s	0.15	0.02 – 2(5) ppb	-(6)
	Sulfur dioxide (SO_2) Gazeous concentration	AF22 (Environnement SA, France)	n/a	10 s	0.42	1.5 ppb	± max (1.5 ppb - 1%)
		100E (Teledyne API, USA)	n/a	10 s	0.6	0.6 ppb	± max (0.6 ppb - 0.5%)
	Nitrogen oxides (NO_X, NO, NO_2) Gazeous concentration	200E (Teledyne API, USA)	n/a	10 s	0.5	0.4 ppb	± max (0.4 ppb - 0.5%)
	Ozone (O_3) Gazeous concentration	400E (Teledyne API, USA)	n/a	10 s	0.8	0.6 ppb	± max (0.6 ppb - 1%)
	CO_2, CO, CH_4 Gazeous concentration	G2401 (PICARRO, USA)	n/a	5 s	0.35	50 ppb (CO_2); 15 ppb (CO); 1 ppb (CH_4)	± 50 ppb (CO_2); ± 15 ppb (CO); ± 1 ppb (CH_4)
	Ammoniac (NH_3) Gazeous concentration	G2103 (PICARRO, USA)	n/a	5 s	1.5	0.03 ppb	±0.058 - 0.19 ppb
AUXILIARY DATA	**Wind speed (ws), wind direction (wd), Temperature (T)** Meteorological data	Weather station (2D)	n/a	1 min	n/a	0.4 $m.s^{-1}$ (ws)	± max (0.2 $m.s^{-1}$ - 1%) (ws); ± 3° (wd)
		Weather station (3D sonic)	n/a	10 s	n/a	0.2 $m.s^{-1}$ (ws)	± max (0.1 $m.s^{-1}$ - 1%) (ws); ± 1° (wd)

(1) aerodynamic diameter; (2) electrical mobility diameter; (3) optical diameter (4) N is the number of particles measured (5) specific to each compound (6) defined for each measurement and compound

Table S2. Quality control of the instruments used during the campaign. The term n/a means not applicable.

	Measured Quantity	Instrument	Calibration	Calibration checks	Flow checks	Blank or zero checks
PARTICULATE PHASE	**Particle number (PN)** Particle number concentration (PNC)	CPC TSI 3776 (TSI, Germany)	annual	Intercomparison of CPCs	start and end campaign	1 per week
		Envi CPC 200 (PALAS, Germany)	annual		start and end campaign	1 per week
	Particle size distribution Particle number concentration (PNC)	SMPS 3936 (CPC 3775 - Classifier 3080 - Long DMA) (TSI, Germany)	annual	-	start and end campaign	1 per week
		SMPS 3936 (CPC 3776 - Classifier 3080 - Long DMA) (TSI, Germany)	annual	-	start and end campaign	start and end campaign
	Particle size distribution Particle number and mass concentration (PNC, PM_1, $PM_{2.5}$, PM_{10})	OPC model 1.109 (Grimm Aerosol Technik, Germany)	annual	-	start and end campaign	1 per week
	Black Carbon (BC) Particle mass concentration	MAAP 5012 (ThermoFisher, USA)	annual	Intercomparison of BC analysers	start and end campaign	1 per week
		AE33 (Aerosol Magee Scientific, USA)	annual		start and end campaign	start and end campaign
	Non refractory chemical composition Particle mass concentration	HR-ToF-AMS (Aerodyne, USA)	start and end campaign	-	start and end campaign	1 per week
	Metals composition Particle mass concentration	Xact 625i (Cooper Environment, USA)	start and end campaign	1 per day	start and end campaign	1 per day
GAS PHASE	**Volatils Organic Compounds (VOC)** Gazeous concentration	PTR-ToF-MS 8000 (Ionicon Analytik, Austria)	start and end campaign	1 per 2 weeks	start and end campaign	1 per 2 weeks
	Sulfur dioxide (SO_2) Gazeous concentration	AF22 (Environnement SA, France)	start and end campaign	1 per day	start and end campaign	1 per day
		100E (Teledyne API, USA)	start and end campaign	1 per day	start and end campaign	1 per day
	Nitrogen oxides (NO_X, NO, NO_2) Gazeous concentration	200E (Teledyne API, USA)	start and end campaign	1 per day	start and end campaign	1 per day
	Ozone (O_3) Gazeous concentration	400E (Teledyne API, USA)	start and end campaign	1 per day	start and end campaign	1 per day
	CO_2, CO, CH_4 Gazeous concentration	G2401 (PICARRO, USA)	start and end campaign with 3 levels of standard gas cylinders	1 per week	start and end campaign	1 per week
	Ammoniac (NH_3) Gazeous concentration	G2103 (PICARRO, USA)	start	-	start and end campaign	start and end campaign
AUXILIARY DATA	**Wind speed (ws), wind direction (wd), Temperature (T)** Meteorological data	Weather station (2D)	start and end campaign	1 per week	n/a	n/a
		Weather station (3D sonic)	start and end campaign	1 per week	n/a	n/a

Table S3. Main organic molecules studied by PTR-ToF-MS during the field campaign in the port of Marseille at PEB station.

Exact mass (m/z)	Chemical formula	Assigned chemical compound	Detection Limit (DL) (ppb)	Uncertainty median (ppb)
33.034	CH_4OH^+	Methanol	0.25	0.70
43.054	$C_3H_6H^+$	Propene and unspecified hydrocarbon fragments	0.29	0.93
45.034	$C_2H_4OH^+$	Acetaldehyde	0.25	0.41
47.013	$CH_2O_2H^+$	Formic acid	0.28	0.60
47.049	$C_2H_6OH^+$	Ethanol	0.17	0.36
57.070	$C_4H_8H^+$	Butene	1.92	4.20
59.049	$C_3H_6OH^+$	Acetone	0.2	0.26
61.028	$C_2H_4O_2H^+$	Acetic acid	0.34	0.98
63.023	$C_2H_6SH^+$	DMS	0.08	0.07
69.070	$C_5H_8H^+$	Isoprene	0.08	0.11
71.049	$C_4H_6OH^+$	MVK, methacrolein, crotonaldehyde	0.04	0.09
71.086	$C_5H_{10}H^+$	Pentene	0.14	0.86
73.065	$C_4H_8OH^+$	Butanone or butanal	0.05	0.07
75.044	$C_3H_6O_2H^+$	Methyl acetate	0.09	0.16
79.054	$C_6H_6H^+$	Benzene	0.08	0.53
83.086	$C_6H_{10}H^+$	Cyclohexene	0.05	0.56
85.101	$C_6H_{12}H^+$	Hydrocarbon	0.08	0.63
87.080	$C_5H_{10}OH^+$	3-methyl-2-butanone, methylbutanals, pentanones	0.07	0.26
89.060	$C_4H_8O_2H^+$	Ethyl acetate	0.05	0.07
93.070	$C_7H_8H^+$	Toluene	0.04	0.07
93.091	$C_4H_{12}O_2H^+$	Dimethyl ether ethanol	0.03	0.03
97.101	$C_7H_{12}H^+$	Cycloheptene	0.05	0.31
99.044	$C_6H_{10}OH^+$	2-methanolfuranone	0.04	0.57
101.06	$C_5H_8O_2H^+$	Pentadione	0.05	0.71
101.096	$C_6H_{12}OH^+$	Hexanals, Hexanones	0.04	0.07
105.070	$C_8H_8H^+$	Styrene	0.04	0.38
107.070	$C_4H_{10}O_3H^+$	Diethylene glycol	0.04	0.02
107.086	$C_8H_{10}H^+$	C8 Aromatics	0.04	0.07
111.117	$C_8H_{14}H^+$	Hydrocarbon	0.04	0.79
117.091	$C_6H_{12}O_2H^+$	Butylesteraceticacid, Other C6 esters	0.03	0.14
121.101	$C_9H_{12}H^+$	C9 Aromatics	0.06	0.42
135.117	$C_{10}H_{14}H^+$	C10 Aromatics	0.03	0.07
137.132	$C_{10}H_{16}H^+$	Monoterpenes	0.05	0.34
139.148	$C_{10}H_{18}H^+$	Decahydronaphthalene	0.03	0.25
143.143	$C_9H_{18}OH^+$	Nonanone	0.05	0.24
149.132	$C_{11}H_{16}H^+$	C11 Aromatics	0.03	0.02
151.112	$C_{10}H_{14}OH^+$	Terpenes	0.02	0.01
151.148	$C_{11}H_{18}H^+$	(3E)-4,8-Dimethylnona-1,3,7-triene / 1-Methyladamantane	0.02	0.03
153.127	$C_{10}H_{16}OH^+$	Camphor, Other oxygenated monoterpenes	0.02	0.02
153.164	$C_{11}H_{20}H^+$	n/a	0.02	0.02
165.164	$C_{12}H_{20}H^+$	1-Ethyladamantane	0.02	0.01

Table S4. Classification of ship categories according to significance

Importance	Ship category
Important ships	Container Ship, Ro-Ro Cargo, Vehicles Carrier, Ro-Ro/Container Carrier, Dredger, Passenger Ship (Cruise), Ro-Ro/Passenger Ship (Ro-Ro Ferry), Buoy-Laying Vessel, Research/Survey Vessel, Fishing, Cement Carrier, Crude Oil Tanker, Oil/Chemical Tanker, Anchor Handling Vessel, Cargo/Containership, General Cargo, Supply Vessel, Tug
Other ships	Port Tender, Passenger, Pilot Vessel, Unspecified SAR, Dive Vessel, Reserved, Patrol Vessel, Law Enforce, Yacht, Pollution Control Vessel, Military Ops, Other

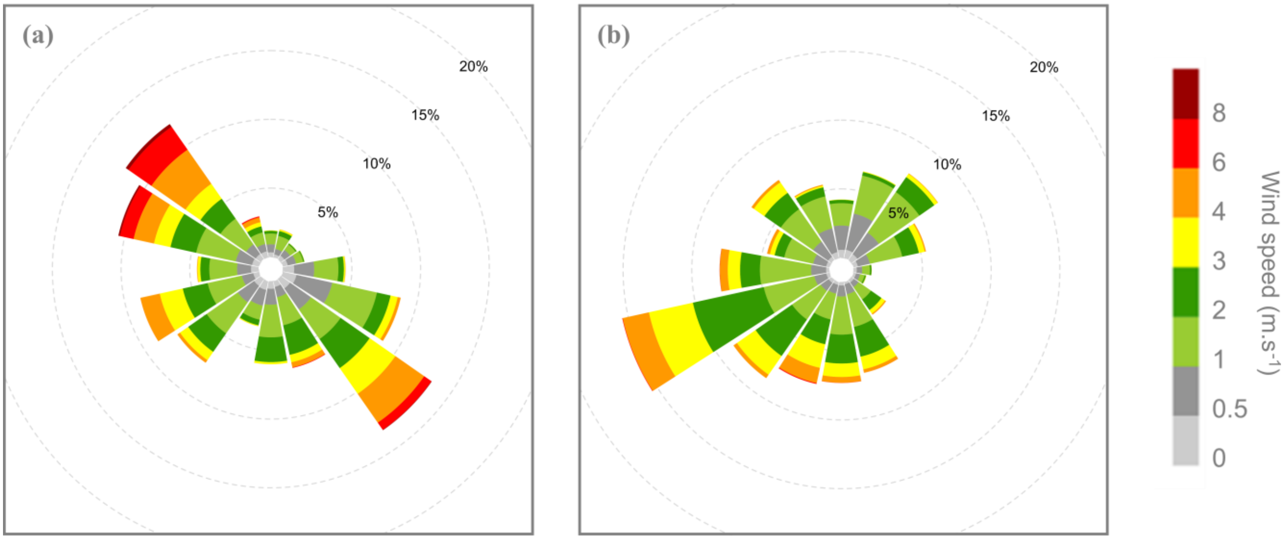


Figure S1. Wind roses diagram (displayed as frequency of counts by wind direction and speed bin) during the monitoring campaign at PEB station (a) and at MAJOR station (b).

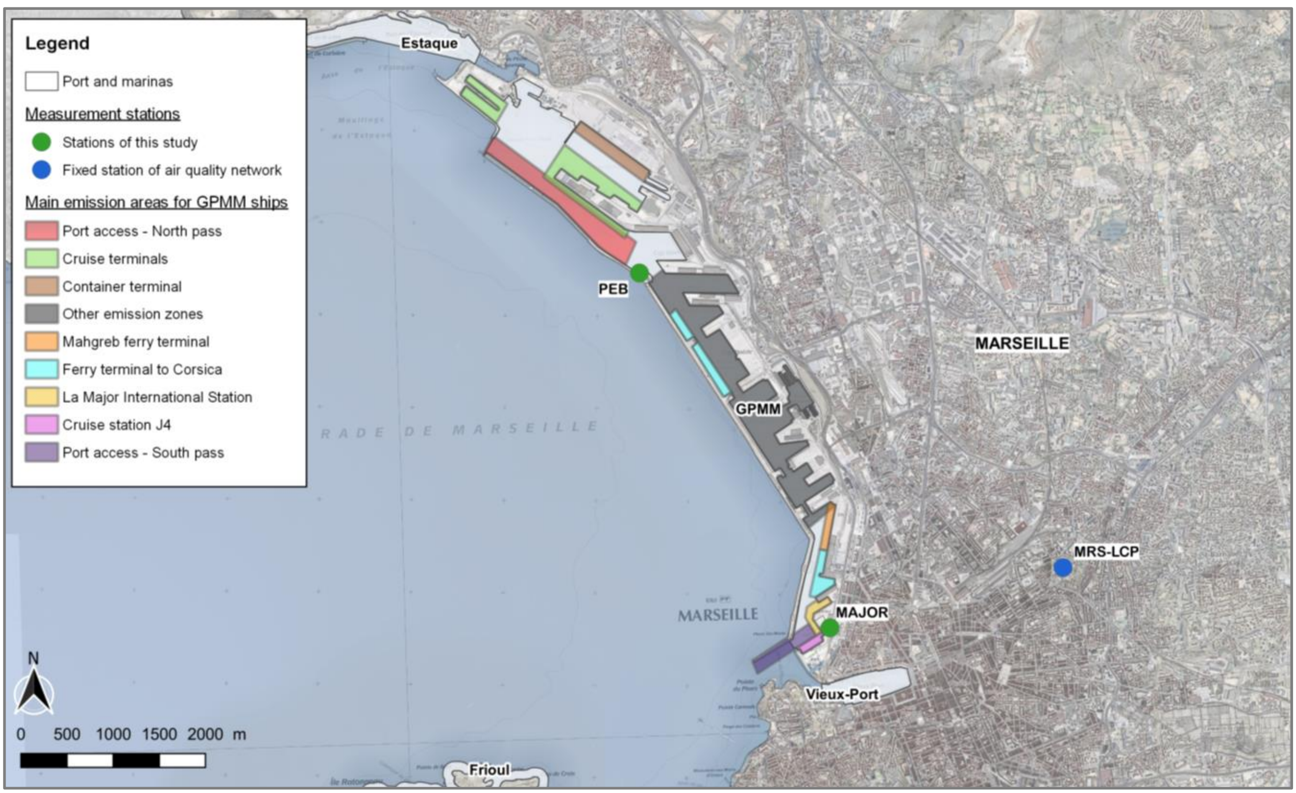


Figure S2. Map of the port of Marseille (GPMM) and marinas with the measurement stations of this study (filled green circle) and the fixed station of air quality network (filled blue circle) as well as the main areas of ship emissions in GPMM. Maps taken from Google satellite images (© Google Maps) and topographic map SCAN 25 (© IGN – 2022).

Table S5. Probability of measurement stations being downwind of the main ship emission areas during the campaign

Station	Main areas of ship emissions (Figure S2.)	Probability to be downwind of ship emissions (%)	Associated wind speeds (m/s) Average (Q1 - Q3)
PEB	Port access - North channel	17%	3.4 (1.5 - 5.4)
	Cruise and container terminals	10%	2.6 (0.9 - 3.9)
	Other emission areas	15%	3.2 (1.3 - 5.1)
MAJOR	Port access - South channel and J4 cruise terminal	13%	2.6 (1.8 - 3.2)
	Other emission areas	8%	1.3 (0.8 - 1.6)

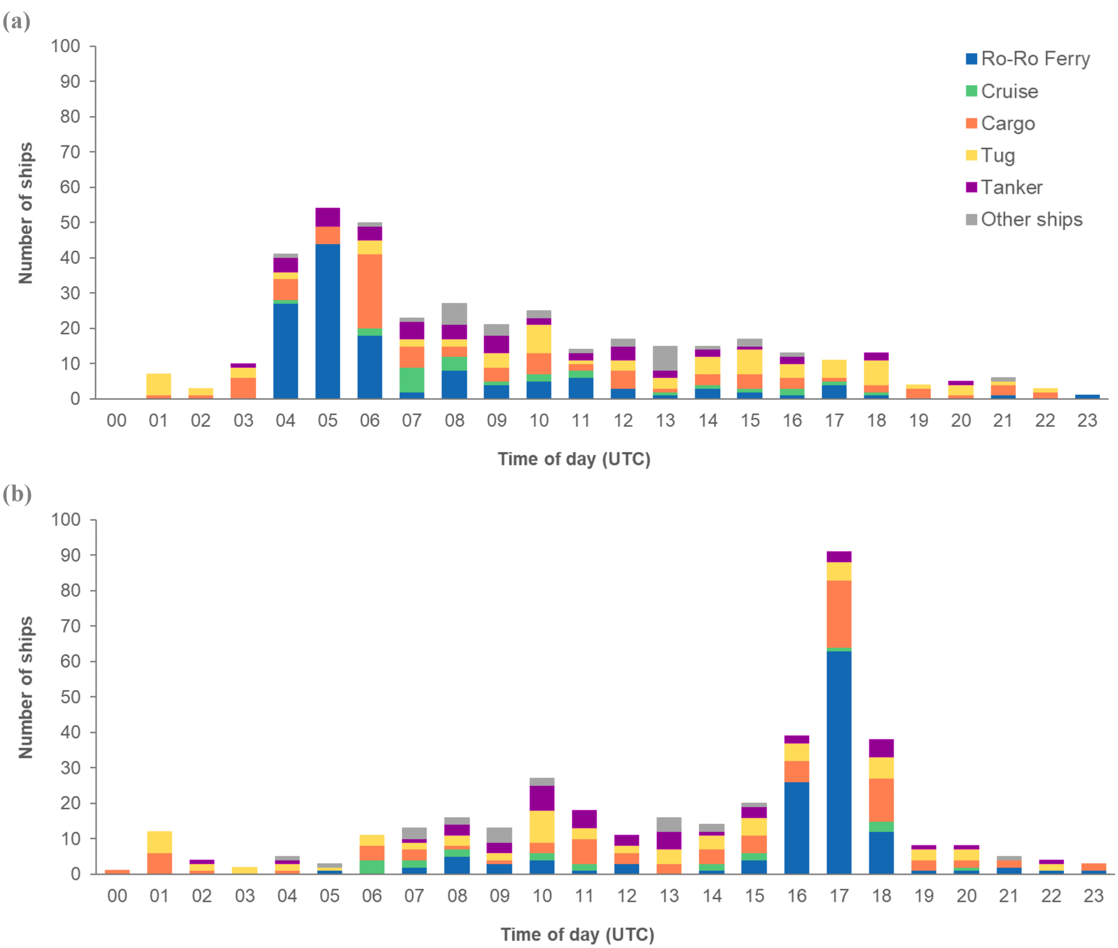


Figure S3. Cumulative number of ship arrivals (a) and departures (b) in the port of Marseille in June 2021 by time of day and ship category (excluding pilot boats, pleasure crafts and passenger shuttles) (MarineTraffic, 2022).

Table S6. Main statistical parameters (25th percentile, mean, median, 75th percentile and maximum) of all compound's concentrations measured at both stations of this study (PEB and MAJOR) and at fixed station of air quality network (MRS-LCP).

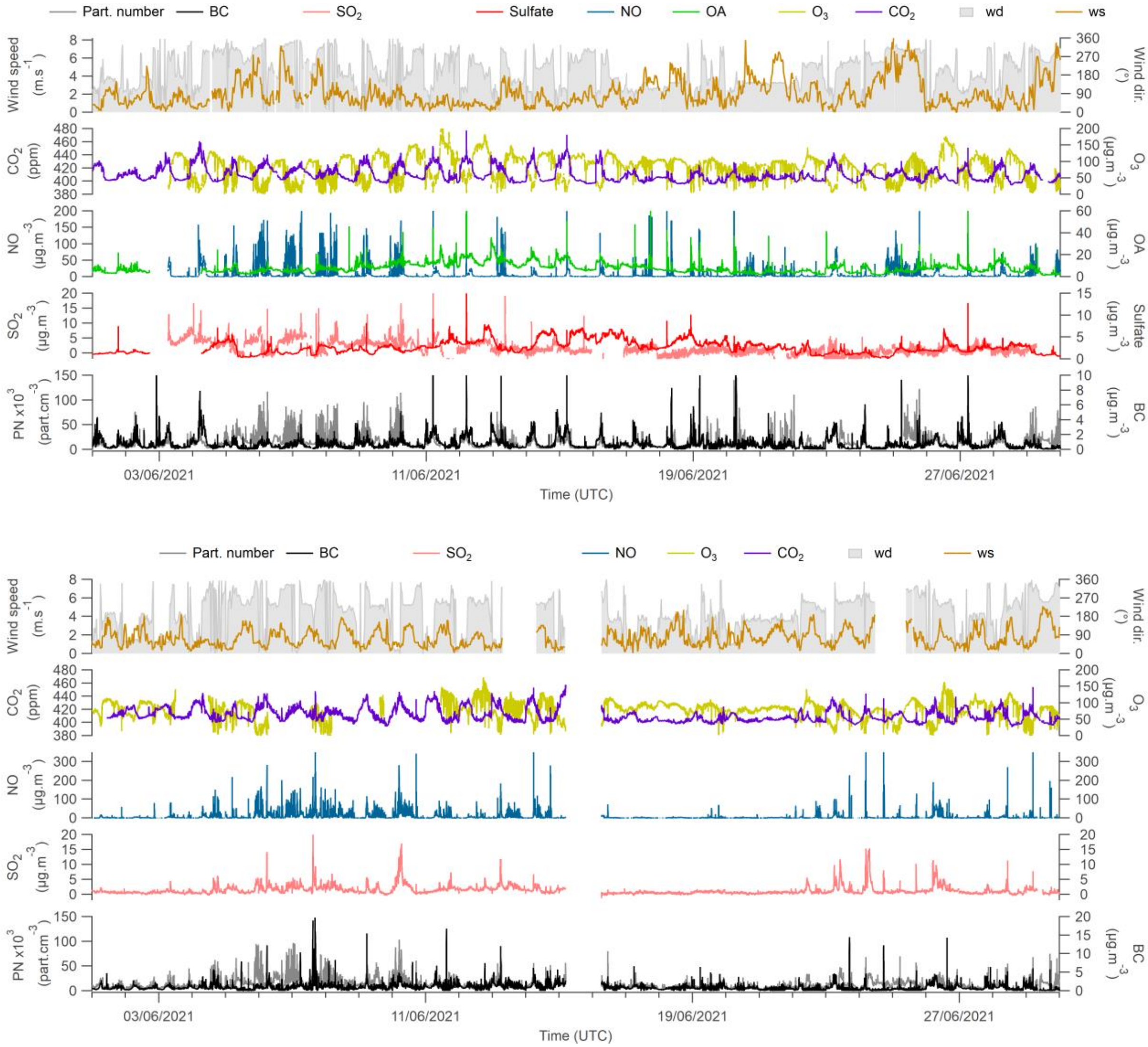
Mesured Quantity	Species	Unit	Site	Time resolution	N	P25	Median	Mean	P75	Max	Missing	DL
PARTICULATE PHASE												
Particle number	PN (2.5 nm - 3 µm)	part.cm^{-3}	PEB	10 sec	259 201	4 939	10 612	13 734	18 098	219 270	13%	
	PN (7 nm - 2.5 µm)	part.cm^{-3}	MAJOR	10 sec	259 201	6 708	10 156	12 751	15 306	116 457	6%	
Particle size distribution	PN (15 nm - 660 nm)	part.cm^{-3}	PEB	5 min	8 641	5 473	10 723	12 449	16 365	87 566	19%	
			MAJOR*	5 min	8 641	7 750	10 907	12 744	15 431	80 330	40%	
			MRS-LCP	5 min	8 641	4 249	6 735	7 661	9 747	112 637	9%	
	PN (250 nm - 32 µm)	part.cm^{-3}	PEB	1 min	43 201	65	102	117	151	1 673	1%	
			MAJOR	1 min	43 201	63	99	110	140	1 204	9%	
Particle masse concentration	PM_{10}	µg.m^{-3}	PEB	1 min	43 201	9.0	14.9	16.7	22.4	153.6	1%	0.2
			MAJOR	1 min	43 201	7.2	10.6	11.6	14.9	89.8	9%	0.2
			MRS-LCP	1 min	43 201	12.1	16.0	20.0	22.6	139.7	11%	0.2
	$PM_{2.5}$	µg.m^{-3}	PEB	1 min	43 201	6.0	11.2	12.7	18.0	109.5	1%	0.2
			MAJOR	1 min	43 201	6.0	9.0	9.8	12.8	83.8	9%	0.2
			MRS-LCP	1 min	43 201	5.0	7.3	8.1	9.9	28.5	11%	0.2
	PM_1	µg.m^{-3}	PEB	1 min	43 201	3.4	8.0	8.9	13.1	107.2	1%	0.2
			MAJOR	1 min	43 201	4.6	7.3	7.8	10.1	70.2	9%	0.2
			MRS-LCP	1 min	43 201	3.2	5.1	5.4	7.2	18.0	11%	0.2
Chemical Composition	BC	µg.m^{-3}	PEB	1 min	43 201	0.3	0.5	0.7	0.9	22.8	1%	0.3
			MAJOR	1 min	43 201	0.4	0.7	0.9	1.2	19.7	4%	0.3
			MRS-LCP	1 min	43 201	0.5	0.7	0.9	1.1	56.1	4%	0.3
	Cl^-	µg.m^{-3}	PEB	30 sec	86 401	< DL	< DL	0.04	0.04	0.97	6%	0.03
	NH_4^+	µg.m^{-3}	PEB	30 sec	86 401	0.52	0.80	0.90	1.13	3.68	6%	0.04
	NO_3^-	µg.m^{-3}	PEB	30 sec	86 401	0.14	0.22	0.34	0.38	5.75	6%	0.04
	OA	µg.m^{-3}	PEB	30 sec	86 401	4.3	6.5	7.6	9.7	163.9	6%	0.4
	SO_4^{2-}	µg.m^{-3}	PEB	30 sec	86 401	1.5	2.4	2.6	3.3	29.1	6%	0.03
Metals Composition	Ag	ng.m^{-3}	PEB	30 min	1 236	< DL	< DL	< DL	< DL	29	11%	10
	Al	ng.m^{-3}	PEB	30 min	1 236	< DL	< DL	< DL	< DL	3 296	11%	2 029
			MRS-LCP	120 min	360	< DL	< DL	< DL	< DL	315	2%	61
	As	ng.m^{-3}	PEB	30 min	1 236	< DL	< DL	0.4	0.5	4.8	11%	0.3
			MRS-LCP	120 min	360	< DL	< DL	< DL	< DL	< DL	2%	0.04
	Au	ng.m^{-3}	PEB	30 min	1 236	< DL	< DL	< DL	< DL	1.1	11%	0.5
			MRS-LCP	120 min	360	< DL	< DL	< DL	< DL	0.8	2%	0.2
	Ba	ng.m^{-3}	PEB	30 min	1 236	< DL	< DL	< DL	< DL	33.9	11%	1.9
	Bi	ng.m^{-3}	PEB	30 min	1 236	< DL	< DL	< DL	< DL	4.4	11%	0.6
			MRS-LCP	120 min	360	< DL	< DL	< DL	< DL	2.2	2%	0.1
	Br	ng.m^{-3}	PEB	30 min	1 236	1.6	2.5	3.2	3.7	147.5	11%	0.5
			MRS-LCP	120 min	360	2.1	3.1	3.4	4.1	41.4	2%	0.1
	Ca	ng.m^{-3}	PEB	30 min	1 236	< DL	< DL	28	21	1 076	11%	19
			MRS-LCP	120 min	360	7	13	39	27	1 188	2%	2
	Cd	ng.m^{-3}	PEB	30 min	1 236	< DL	< DL	< DL	< DL	39	11%	18
			MRS-LCP	120 min	360	< DL	< DL	< DL	< DL	3.0	2%	1.8
	Ce	ng.m^{-3}	PEB	30 min	1 236	< DL	< DL	< DL	< DL	3.6	11%	1.5
	Cl	ng.m^{-3}	PEB	30 min	1 236	< DL	< DL	23	25	305	11%	19
			MRS-LCP	120 min	360	< DL	4.0	13.1	13.2	226.5	2%	3.4
	Co	ng.m^{-3}	PEB	30 min	1 236	< DL	< DL	< DL	< DL	1.8	11%	0.7
			MRS-LCP	120 min	360	< DL	< DL	< DL	< DL	0.3	2%	0.1
	Cr	ng.m^{-3}	PEB	30 min	1 236	< DL	< DL	< DL	< DL	20.3	11%	0.6
			MRS-LCP	120 min	360	< DL	< DL	0.2	0.1	24.7	2%	0.1
	Cs	ng.m^{-3}	PEB	30 min	1 236	< DL	< DL	< DL	< DL	6.5	11%	1.9
	Cu	ng.m^{-3}	PEB	30 min	1 236	< DL	< DL	1.3	1.2	52.8	11%	1.0
			MRS-LCP	120 min	360	0.9	1.2	2.0	1.8	55.7	2%	0.6
	Fe	ng.m^{-3}	PEB	30 min	1 236	7	12	22	23	654	11%	6
			MRS-LCP	120 min	360	12	20	33	36	413	2%	1

Mesured Quantity	Species	Unit	Site	Time resolution	N	P25	Median	Mean	P75	Max	Missing	DL
PARTICULATE PHASE												
Metals Composition	Ga	$ng.m^{-3}$	PEB	30 min	1 236	< DL	< DL	< DL	< DL	0.7	11%	0.3
			MRS-LCP	120 min	360	< DL	< DL	< DL	< DL	< DL	2%	0.1
	Ge	$ng.m^{-3}$	PEB	30 min	1 236	< DL	< DL	< DL	< DL	0.6	11%	0.3
			MRS-LCP	120 min	360	< DL	< DL	< DL	< DL	< DL	2%	0.0
	Hg	$ng.m^{-3}$	PEB	30 min	1 236	< DL	< DL	< DL	< DL	1.3	11%	0.6
			MRS-LCP	120 min	360	0.4	0.4	0.3	0.4	0.4	2%	0.1
	I	$ng.m^{-3}$	PEB	30 min	1 236	< DL	< DL	< DL	< DL	185.0	11%	55.0
	In	$ng.m^{-3}$	PEB	30 min	1 236	< DL	< DL	< DL	< DL	44.5	11%	15.0
	K	$ng.m^{-3}$	PEB	30 min	1 236	8	14	20	25	398	11%	6
			MRS-LCP	120 min	360	20	26	32	38	162	2%	1
	La	$ng.m^{-3}$	PEB	30 min	1 236	< DL	< DL	< DL	< DL	4.7	11%	1.8
	Mn	$ng.m^{-3}$	PEB	30 min	1 236	< DL	< DL	< DL	< DL	29.3	11%	0.7
			MRS-LCP	120 min	360	< DL	< DL	0.3	0.3	4.6	2%	0.1
	Mo	$ng.m^{-3}$	PEB	30 min	1 236	< DL	< DL	< DL	< DL	7.4	11%	2.4
			MRS-LCP	120 min	360	< DL	< DL	< DL	< DL	< DL	2%	0.3
	Ni	$ng.m^{-3}$	PEB	30 min	1 236	< DL	< DL	1.5	1.5	44.1	11%	0.6
			MRS-LCP	120 min	360	0.3	0.8	1.1	1.3	9.9	2%	0.2
	P	$ng.m^{-3}$	PEB	30 min	1 236	< DL	< DL	< DL	< DL	38.0	11%	33.8
	Pb	$ng.m^{-3}$	PEB	30 min	1 236	< DL	< DL	< DL	< DL	31.2	11%	0.6
			MRS-LCP	120 min	360	1.2	1.9	2.7	3.2	43.6	2%	0.2
	Pd	$ng.m^{-3}$	PEB	30 min	1 236	< DL	< DL	< DL	< DL	127	11%	56
			MRS-LCP	120 min	360	< DL	< DL	< DL	< DL	8	2%	7
	Pt	$ng.m^{-3}$	PEB	30 min	1 236	< DL	< DL	< DL	< DL	0.9	11%	0.6
			MRS-LCP	120 min	360	< DL	< DL	< DL	< DL	< DL	2%	0.1
	Rb	$ng.m^{-3}$	PEB	30 min	1 236	< DL	< DL	< DL	< DL	2.5	11%	1.0
	S	$ng.m^{-3}$	PEB	30 min	1 236	356	596	639	857	1 711	11%	16
			MRS-LCP	120 min	360	411	605	668	849	1 697	2%	2
	Sb	$ng.m^{-3}$	PEB	30 min	1 236	< DL	< DL	< DL	< DL	91	11%	50
			MRS-LCP	120 min	360	< DL	< DL	< DL	< DL	11	2%	3
	Sc	$ng.m^{-3}$	PEB	30 min	1 236	< DL	< DL	< DL	< DL	3.2	11%	1.5
	Se	$ng.m^{-3}$	PEB	30 min	1 236	< DL	< DL	< DL	< DL	3.2	11%	0.4
			MRS-LCP	120 min	360	0.1	0.2	0.2	0.3	1.1	2%	0.1
	Si	$ng.m^{-3}$	PEB	30 min	1 236	< DL	< DL	< DL	< DL	165	11%	89
			MRS-LCP	120 min	360	< DL	< DL	25	< DL	704	2%	11
	Sn	$ng.m^{-3}$	PEB	30 min	1 236	< DL	< DL	< DL	< DL	138	11%	20
			MRS-LCP	120 min	360	< DL	< DL	< DL	< DL	< DL	2%	2.5
	Sr	$ng.m^{-3}$	PEB	30 min	1 236	< DL	< DL	< DL	< DL	12.5	11%	1.1
	Te	$ng.m^{-3}$	PEB	30 min	1 236	< DL	< DL	< DL	< DL	149	11%	79
	Ti	$ng.m^{-3}$	PEB	30 min	1 236	< DL	< DL	< DL	< DL	43	11%	1
			MRS-LCP	120 min	360	0.2	0.4	1.1	0.8	26.2	2%	0.2
	Tl	$ng.m^{-3}$	PEB	30 min	1 236	< DL	< DL	< DL	< DL	0.9	11%	0.6
			MRS-LCP	120 min	360	< DL	< DL	< DL	< DL	< DL	2%	0.1
	V	$ng.m^{-3}$	PEB	30 min	1 236	< DL	< DL	1.2	1.1	46.0	11%	0.6
			MRS-LCP	120 min	360	0.2	0.7	1.0	1.4	10.1	2%	0.1
	Y	$ng.m^{-3}$	PEB	30 min	1 236	< DL	< DL	< DL	< DL	3.2	11%	1.4
			MRS-LCP	120 min	360	< DL	< DL	< DL	< DL	1.0	2%	0.7
	Zn	$ng.m^{-3}$	PEB	30 min	1 236	< DL	4.0	6.5	6.4	309.5	11%	4.0
			MRS-LCP	120 min	360	3.4	5.0	6.1	7.0	37.9	2%	0.3
	Zr	$ng.m^{-3}$	PEB	30 min	1 236	< DL	< DL	< DL	< DL	3.0	11%	1.6
			MRS-LCP	120 min	360	< DL	< DL	< DL	< DL	1.6	2%	0.4

* Data corrected with CPC data

Mesured Quantity	Species	Unit	Site	Time resolution	N	P25	Median	Mean	P75	Max	Missing	DL
GAS PHASE												
Nitrogen Oxides	NO_X	$\mu g.m^{-3}$	PEB	10 sec	259 201	6.3	15.1	33.9	42.4	2 046.2	22%	0.7
			MAJOR	10 sec	259 201	8.6	15.3	31.3	36.3	1 423.1	6%	0.7
			MRS-LCP	10 sec	259 201	11.1	16.4	22.8	26.2	932.3	2%	0.7
	NO_2	$\mu g.m^{-3}$	PEB	10 sec	259 201	5.2	12.8	22.3	34.4	508.2	22%	0.7
			MAJOR	10 sec	259 201	7.1	13.0	20.8	28.7	395.8	5%	0.7
			MRS-LCP	10 sec	259 201	9.0	13.8	18.7	22.2	467.3	2%	0.7
	NO	$\mu g.m^{-3}$	PEB	10 sec	259 201	0.6	1.1	7.6	4.1	1 180.9	22%	0.5
			MAJOR	10 sec	259 201	< DL	1.1	6.7	3.7	895.1	6%	0.5
			MRS-LCP	10 sec	259 201	1.0	1.5	2.7	2.6	545.7	2%	0.5
Carbon Oxides	CO_2	ppm	PEB	10 sec	259 201	401.7	406.5	409.8	415.1	492.8	1%	0.05
			MAJOR	10 sec	259 201	402.9	407.4	410.4	415.6	484.0	5%	0.05
			MRS-LCP	10 sec	259 201	418.1	422.7	426.0	431.3	565.3	1%	0.05
	CO	ppm	PEB	10 sec	259 201	0.2	0.2	0.2	0.2	0.9	1%	0.02
			MAJOR	10 sec	259 201	0.1	0.1	0.1	0.2	11.4	5%	0.02
Sulfur Dioxide	SO_2	$\mu g.m^{-3}$	PEB	10 sec	259 201	< DL	< DL	1.5	2.9	35.7	30%	1.3
			MAJOR	10 sec	259 201	< DL	< DL	1.4	1.6	31.6	7%	1.3
			MRS-LCP	10 sec	259 201	< DL	1.4	1.4	1.8	14.0	8%	1.3
Ozone	O_3	$\mu g.m^{-3}$	PEB	10 sec	259 201	53.6	88.0	82.1	108.0	206.4	23%	1.2
			MAJOR	10 sec	259 201	65.0	81.8	78.4	95.4	179.0	25%	1.2
			MRS-LCP	10 sec	259 201	59.0	77.4	76.5	93.2	181.6	3%	1.2
Ammoniac	NH_3	ppb	PEB	10 sec	259 201	2.34	2.98	3.17	3.74	11.35	60%	0.03
Volatils Organics Compounds (VOC)	CH_4	ppm	PEB	10 sec	259 201	2.231	2.254	2.278	2.293	3.544	1%	0.001
			MAJOR	10 sec	259 201	1.973	1.998	2.021	2.038	3.054	5%	0.001
			MRS-LCP	10 sec	259 201	1.980	2.010	1.997	2.030	2.240	1%	0.001
	$(CH_2O_2)H^+$	ppb	PEB	10 sec	259 201	3.59	5.11	4.78	5.89	8.22	20%	0.28
	$(CH_3OH)H^+$	ppb	PEB	10 sec	259 201	2.74	4.32	4.92	6.21	15.86	20%	0.25
	$(C_2H_4O)H^+$	ppb	PEB	10 sec	259 201	1.32	1.72	2.11	2.59	9.14	20%	0.25
	$(C_2H_4O_2)H^+$	ppb	PEB	10 sec	259 201	2.57	3.38	3.83	4.49	62.82	20%	0.34
	$(C_2H_6O)H^+$	ppb	PEB	10 sec	259 201	0.91	1.70	1.97	2.34	34.77	20%	0.17
	$(C_2H_6S)H^+$	ppb	PEB	10 sec	259 201	< DL	< DL	0.10	0.17	1.20	20%	0.08
	$(C_3H_6)H^+$	ppb	PEB	10 sec	259 201	0.31	0.46	0.55	0.70	5.81	20%	0.29
	$(C_3H_6O)H^+$	ppb	PEB	10 sec	259 201	1.46	1.89	2.10	2.47	16.68	20%	0.20
	$(C_3H_6O_2)H^+$	ppb	PEB	10 sec	259 201	< DL	0.15	0.18	0.26	1.26	20%	0.09
	$(C_4H_{10}O_3)H^+$	ppb	PEB	10 sec	259 201	< DL	< DL	< DL	< DL	1.31	20%	0.04
	$(C_4H_{12}O_2)H^+$	ppb	PEB	10 sec	259 201	< DL	< DL	< DL	0.04	0.70	20%	0.03
	$(C_4H_6O)H^+$	ppb	PEB	10 sec	259 201	< DL	0.05	0.07	0.11	0.56	20%	0.04
	$(C_4H_8)H^+$	ppb	PEB	10 sec	259 201	< DL	< DL	< DL	2.36	19.97	20%	1.92
	$(C_4H_8O)H^+$	ppb	PEB	10 sec	259 201	0.08	0.13	0.18	0.23	3.48	20%	0.05
	$(C_4H_8O_2)H^+$	ppb	PEB	10 sec	259 201	< DL	< DL	0.09	0.09	4.71	20%	0.05
	$(C_5H_{10})H^+$	ppb	PEB	10 sec	259 201	< DL	< DL	0.14	0.17	3.04	20%	0.14
	$(C_5H_{10}O)H^+$	ppb	PEB	10 sec	259 201	0.10	0.18	0.19	0.28	0.74	20%	0.07
	$(C_5H_8)H^+$	ppb	PEB	10 sec	259 201	< DL	0.11	0.12	0.19	0.66	20%	0.08
	$(C_5H_8O_2)H^+$	ppb	PEB	10 sec	259 201	0.06	0.12	0.12	0.16	0.61	20%	0.05
	$(C_6H_{10})H^+$	ppb	PEB	10 sec	259 201	< DL	0.05	0.07	0.09	0.49	20%	0.05
	$(C_6H_{10}O)H^+$	ppb	PEB	10 sec	259 201	< DL	< DL	< DL	0.04	0.26	20%	0.04
	$(C_6H_{12})H^+$	ppb	PEB	10 sec	259 201	< DL	< DL	< DL	< DL	0.89	20%	0.08
	$(C_6H_{12}O)H^+$	ppb	PEB	10 sec	259 201	< DL	< DL	< DL	< DL	2.13	20%	0.04
	$(C_6H_{12}O_2)H^+$	ppb	PEB	10 sec	259 201	< DL	< DL	< DL	< DL	0.40	20%	0.03
	$(C_6H_6)H^+$	ppb	PEB	10 sec	259 201	< DL	< DL	< DL	< DL	0.98	20%	0.08
	$(C_7H_{12})H^+$	ppb	PEB	10 sec	259 201	< DL	< DL	< DL	0.05	0.29	20%	0.05
	$(C_7H_8)H^+$	ppb	PEB	10 sec	259 201	< DL	0.10	0.22	0.27	6.55	20%	0.04
	$(C_8H_{10})H^+$	ppb	PEB	10 sec	259 201	0.05	0.20	0.37	0.49	18.34	20%	0.04
	$(C_8H_{14})H^+$	ppb	PEB	10 sec	259 201	< DL	< DL	< DL	0.04	0.23	20%	0.04
	$(C_8H_8)H^+$	ppb	PEB	10 sec	259 201	< DL	< DL	< DL	0.05	0.37	20%	0.04

Mesured Quantity	Species	Unit	Site	Time resolution	N	P25	Median	Mean	P75	Max	Missing	DL
GAS PHASE												
Volatils Organics Compounds (VOC)	$(C_9H_{12})H^+$	ppb	PEB	10 sec	259 201	< DL	0.06	0.13	0.13	20.04	20%	0.06
	$(C_9H_{18}O)H^+$	ppb	PEB	10 sec	259 201	< DL	< DL	< DL	0.07	0.42	20%	0.05
	$(C_{10}H_{14})H^+$	ppb	PEB	10 sec	259 201	< DL	< DL	0.03	0.05	2.39	20%	0.03
	$(C_{10}H_{14}O)H^+$	ppb	PEB	10 sec	259 201	< DL	< DL	< DL	< DL	0.09	20%	0.02
	$(C_{10}H_{16})H^+$	ppb	PEB	10 sec	259 201	< DL	0.05	0.07	0.09	0.83	20%	0.05
	$(C_{10}H_{16}O)H^+$	ppb	PEB	10 sec	259 201	< DL	< DL	< DL	< DL	0.11	20%	0.02
	$(C_{10}H_{18})H^+$	ppb	PEB	10 sec	259 201	< DL	< DL	< DL	< DL	0.09	20%	0.03
	$(C_{11}H_{16})H^+$	ppb	PEB	10 sec	259 201	< DL	< DL	< DL	< DL	0.16	20%	0.03
	$(C_{11}H_{18})H^+$	ppb	PEB	10 sec	259 201	< DL	< DL	< DL	< DL	0.08	20%	0.02
	$(C_{11}H_{20})H^+$	ppb	PEB	10 sec	259 201	< DL	< DL	< DL	< DL	0.06	20%	0.02
	$(C_{12}H_{20})H^+$	ppb	PEB	10 sec	259 201	< DL	< DL	< DL	< DL	0.07	20%	0.02



(a)

(b)

Figure S4. Temporal evolution of the main pollutants at the two measurement stations located in the port area (PEB station (a) and MAJOR station (b))

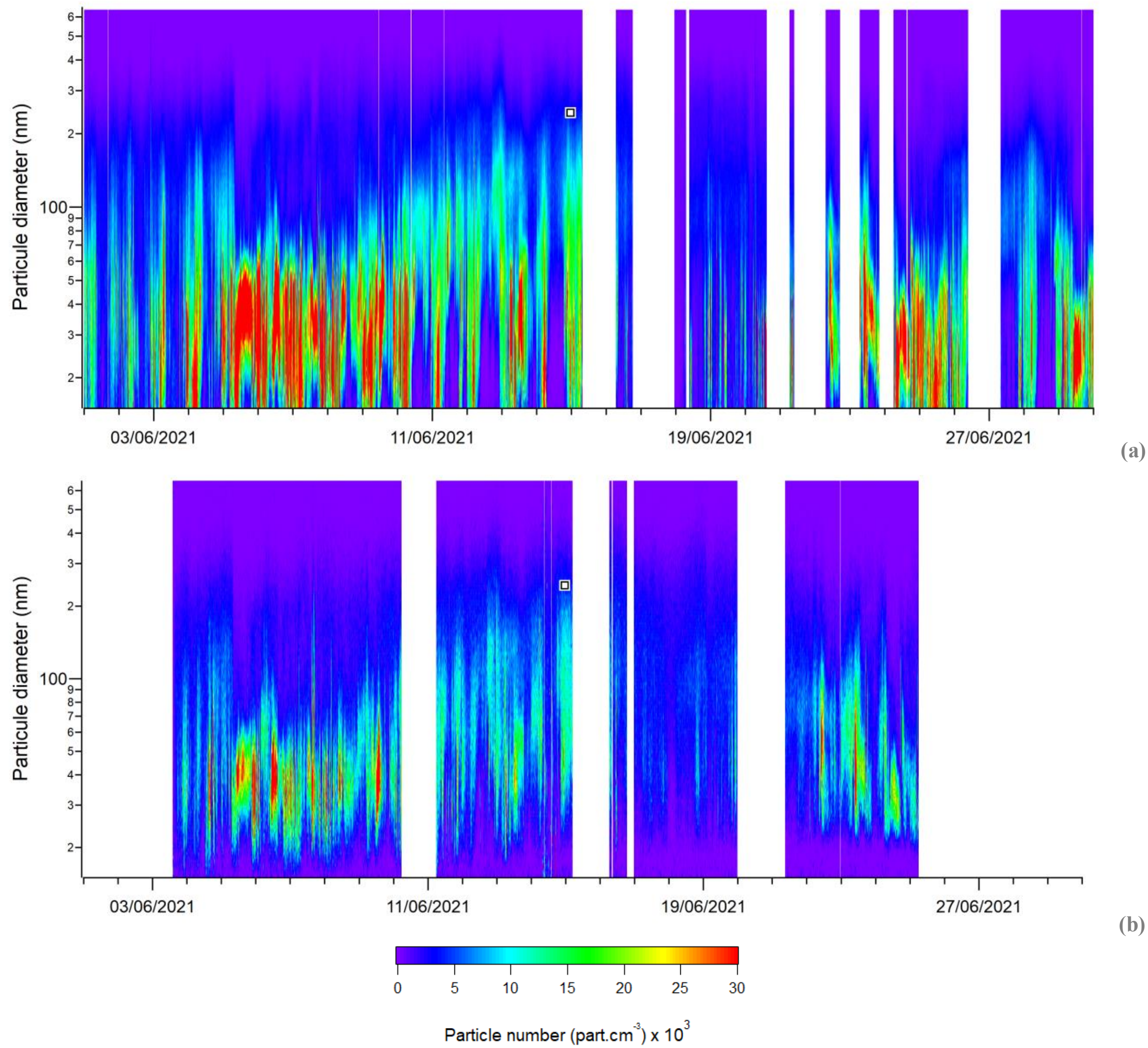


Figure S5. Temporal evolution of the particle size distribution during the campaign at measurement stations located in the port area (PEB station (a) and MAJOR station (b)). The y-axis corresponds to the particle diameter Dp in nm and the colour bar indicates the concentration dN/dlogDp (part.cm^{-3}).

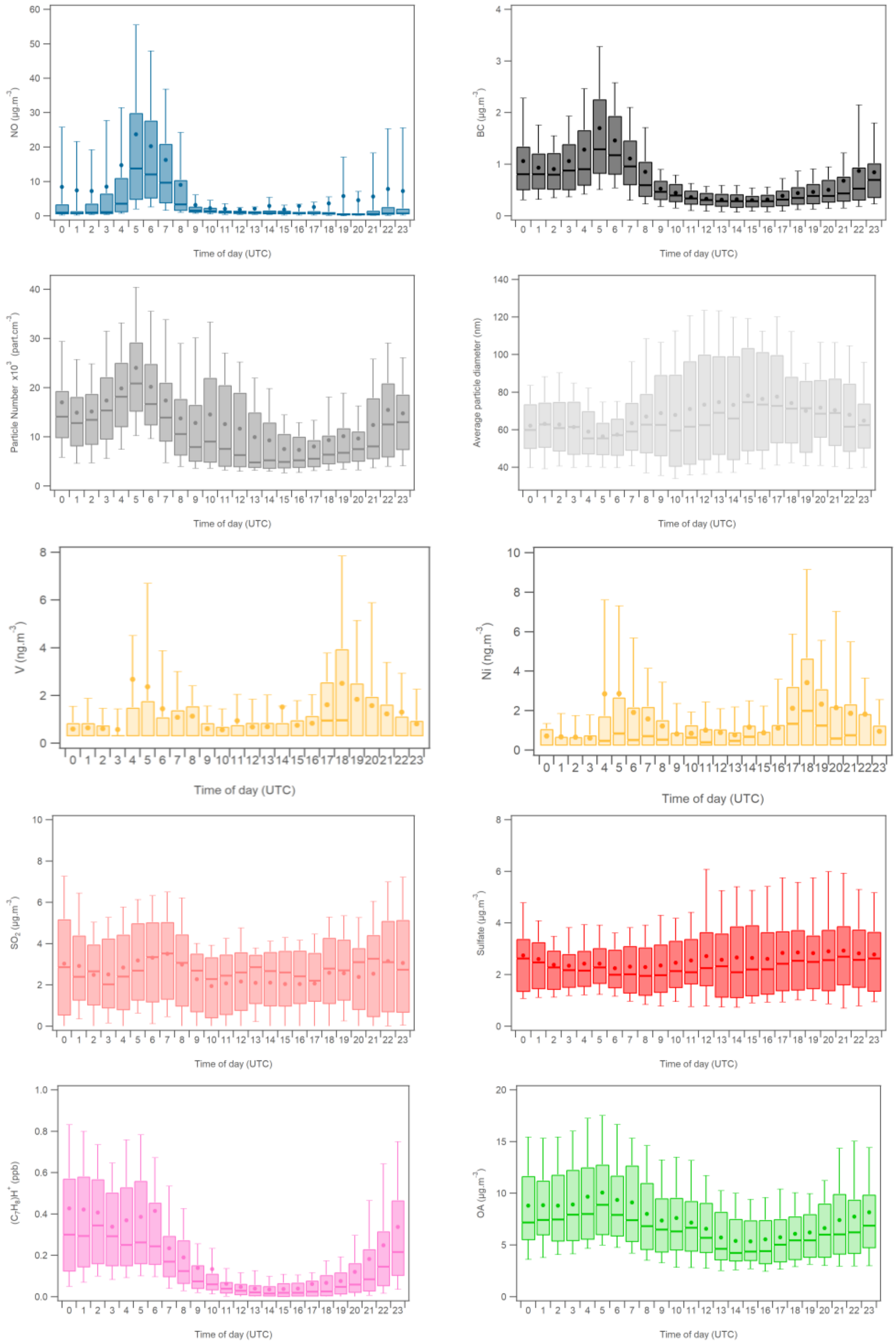


Figure S6. Daily profiles of nitrogen monoxide (NO), black carbon (BC), ultrafine particles and their average diameter, vanadium (V), nickel (Ni), sulphur dioxide (SO_2), sulphate (SO_4^{2-}), toluene ($(C_7H_8)H^+$) and organic aerosol (OA) during the campaign at the PEB station. For each box plot, the coloured box represents the interval between the 25th percentile and the 75th percentile, the vertical error bar represents the interval between the 10th percentile and the 90th percentile, the horizontal line represents the median and the circle represents the mean.

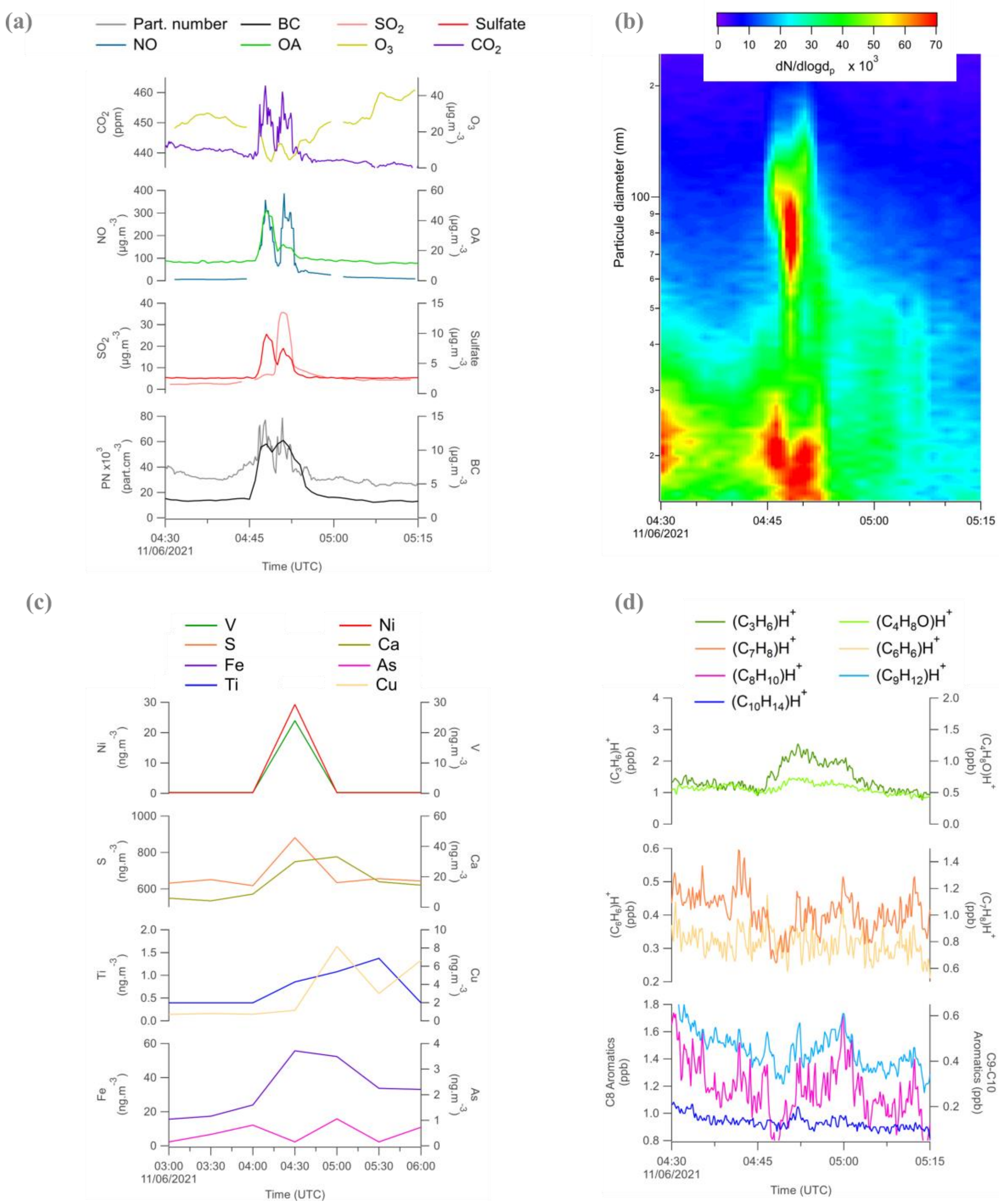


Figure S7. Ship plumes detected at the PEB station on June 11, 2021. Temporal evolution of (a) concentrations of the main pollutants, (b) particle size distribution, (c) concentrations of selected metals, and (d) concentrations of selected NMVOCs measured using PTR-ToF-MS.

Table S7. Sensitivity of emission factors to measurement time resolution for the 353 plumes: median relative deviation from the finest resolution values [values in brackets represent the 25th and 75th percentiles].

Species	Plume duration (min)	N_{plumes}	Temporal resolution compared to 10 s: 30 s	1 min	2 min	5 min
PN	**All**	353	2.8% [1.1% / 6.0%]	5.1% [2.1% / 11.2%]	11.5% [4.3% / 74.5%]	85.7% [19.7% / 130.5%]
	<5	82	3.2% [1.5% / 6.2%]	5.4% [2.8% / 20.7%]	62.3% [7.3% / 100.0%]	100.0% [34.0% / 355.2%]
	5-10	113	2.7% [1.0% / 6.1%]	5.7% [2.1% / 10.3%]	11.2% [3.5% / 45.4%]	100.0% [22.4% / 211.4%]
	10-15	69	3.1% [1.2% / 8.3%]	7.3% [2.2% / 13.9%]	7.9% [4.3% / 27.6%]	94.1% [21.0% / 306.6%]
	15-20	25	3.7% [0.7% / 8.3%]	5.2% [1.9% / 8.3%]	11.6% [5.4% / 46.5%]	55.7% [12.6% / 100.0%]
	20-30	64	2.2% [1.1% / 4.2%]	3.5% [1.9% / 5.6%]	8.0% [3.2% / 19.2%]	27.7% [12.7% / 96.5%]
NO_X	**All**	353	4.5% [2.0% / 9.0%]	10.0% [3.9% / 25.6%]	27.0% [8.4% / 100.0%]	100.0% [28.7% / 100.0%]
	<5	82	4.4% [1.8% / 7.1%]	10.6% [3.1% / 26.1%]	62.8% [11.0% / 100.0%]	100.0% [40.3% / 100.0%]
	5-10	113	4.0% [1.7% / 10.5%]	8.6% [3.3% / 32.2%]	25.9% [6.8% / 100.0%]	100.0% [32.1% / 100.0%]
	10-15	69	5.5% [3.0% / 10.1%]	14.6% [5.7% / 43.9%]	29.0% [11.5% / 73.3%]	100.0% [37.2% / 100.0%]
	15-20	25	5.3% [2.4% / 8.7%]	9.9% [5.5% / 18.3%]	29.7% [14.7% / 86.8%]	79.2% [21.2% / 100.0%]
	20-30	64	4.8% [2.1% / 8.9%]	6.8% [3.8% / 13.6%]	15.2% [6.6% / 35.6%]	47.1% [17.6% / 100.0%]

Table S8. EF literature review: Statistical summary of ship emission factors by fuel type, presented as mean ± standard deviation (number of EFs considered).

	Species	Unit	LNG	Fuel % S < 0.001 %	Fuel % S < 0.1 %	Fuel % S < 0.5 %	Fuel % S < 1.5 %	Fuel % S < 3.5 %
GAS PHASE	**CO_2**	g/(kg fuel)	3 060 ± 1 440 (15)	3 078 ± 225 (2)	3 405 ± 678 (56)	3 317 ± 620 (22)	2 995 ± 166 (35)	2 936 ± 356 (47)
	NO_X	g/(kg fuel)	9.4 ± 8.4 (15)	53.2 ± 32.4 (10)	57.9 ± 30.2 (62)	55.5 ± 16.4 (157)	46.9 ± 22.2 (289)	67.7 ± 18.3 (40)
	NO	g/(kg fuel)	-	-	32.9 ± 1.7 (3)	55.7 ± 18.5 (145)	7.0 ± 1.0 (252)	95.8 ± 24.4 (10)
	NO_2	g/(kg fuel)	-	-	-	11.2 ± 11.5 (145)	35.0 ± 6.0 (252)	9.2 ± 0.7 (10)
	CO	g/(kg fuel)	30.0 ± 51.8 (15)	4.2 ± 2.8 (8)	5.7 ± 8.6 (62)	14.7 ± 9.0 (24)	8.0 ± 5.7 (287)	7.8 ± 8.0 (48)
	SO_2	g/(kg fuel)	0.01 ± 0.00 (2)	1.13 ± 0.70 (8)	1.06 ± 0.98 (34)	4.31 ± 2.60 (151)	19.50 ± 4.27 (257)	39.53 ± 14.44 (26)
	NH_3	g/(kg fuel)	-	-	0.11 ± 0.22 (10)	-	0.05 ± 0.07 (15)	-
	CH_4	g/(kg fuel)	100 ± 239 (15)	-	0.17 ± 0.40 (19)	0.12 ± 0.15 (2)	0.71 ± 0.08 (4)	0.06 ± 0.07 (7)
	NMVOC	mg/(kg fuel)	-	-	551 ± 398 (3)	295 ± 304 (5)	48 ± 38 (7)	113 ± 9 (9)
	O_3	g/(kg fuel)	-	-	-	-	-48 ± 5 (252)	-
PARTICULATE PHASE	**PN**	$.10^{15}$ part/(kg fuel)	2.1 ± 4.1 (20)	6.1 ± 11.1 (19)	8.1 ± 14.1 (4)	18.1 ± 21.1 (225)	4.1 ± 6.1 (255)	13.1 ± 12.1 (65)
	D_{mode}	nm	22.5 ± 16.3 (12)	44.3 ± 23.0 (3)	35.0 (1)	34.5 ± 0.7 (140)	41.0 ± 12.7 (2)	50.5 ± 6.4 (2)
	PM_1	g/(kg fuel)	-	0.07 ± 0.03 (5)	0.61 ± 0.21 (5)	0.88 ± 0.92 (151)	3.77 ± 3.67 (254)	1.26 ± 0.64 (24)
	$PM_{2,5}$	g/(kg fuel)	0.19 ± 0.31 (5)	0.39 ± 0.13 (2)	2.33 ± 3.55 (30)	0.82 ± 0.83 (6)	3.39 ± 3.84 (4)	3.72 ± 3.13 (32)
	PM_{10}	g/(kg fuel)	-	-	0.31 ± 0.04 (2)	1.06 ± 1.01 (6)	1.71 ± 0.24 (3)	2.05 ± 1.33 (12)
	PM_{TOT}	g/(kg fuel)	0.06 ± 0.07 (11)	0.31 ± 0.13 (5)	0.68 ± 0.47 (21)	2.53 ± 1.65 (14)	3.33 ± 1.30 (18)	6.36 ± 3.12 (19)
	BC (PM_1)	g/(kg fuel)	8 ± 7 (24)	98 ± 59 (5)	238 ± 305 (40)	241 ± 392 (201)	351 ± 872 (271)	214 ± 319 (80)
	OA (PM_1)	mg/(kg fuel)	-	-	624 ± 335 (5)	1 350 ± 636 (154)	3 000 ± 1 000 (252)	1 600 ± 700 (23)
	SO_4 (PM_1)	mg/(kg fuel)	-	-	120 ± 50 (5)	300 ± 339 (154)	4 000 ± 1000 (252)	2 100 ± 1 600 (23)
	NH_4 (PM_1)	mg/(kg fuel)	-	-	2 ± 3 (5)	0 ± 1 000 (15)	1 300.0 (252)	0 ± 1 000 (23)
	NO_3 (PM_1)	mg/(kg fuel)	-	-	3 ± 6 (5)	0 ± 1 000 (15)	800.0 (252)	0 ± 1 000 (23)
	Cl^- (PM_1)	mg/(kg fuel)	-	-	0 (5)	15.5 ± 13.2 (4)	15.7 ± 7.8 (15)	-

Note: References for the scientific articles consulted for each compound are summarized in Table S9.

Table S9. Scientific References used in Table S8, Organized by compound

Species		Unit
GAS PHASE	**CO_2**	Aakko-Saksa et al. (2016), Agrawal et al. (2008a), Agrawal et al. (2008b), Agrawal et al. (2010), Anderson et al. (2015a), Bai et al. (2020), Celo et al. (2015), Comer et al. (2017), Cooper et al. (1996), Cooper(2001), Fridell et al. (2008), Gysel et al. (2017), Huang et al. (2018), Lehtoranta et al. (2019), McCaffery et al. (2021), Moldanová et al. (2013), Peng et al. (2020), Timonen et al. (2017), Winnes et al. (2020), Zhao et al. (2020)
	NO_X	Aakko-Saksa et al. (2016), Agrawal et al. (2008a), Agrawal et al. (2008b), Agrawal et al. (2010), Anderson et al. (2015a), Bai et al. (2020), Celik et al. (2020), Celo et al. (2015), Comer et al. (2017), Cooper et al. (1996), Cooper(2001), Diesch et al. (2013), Fridell and Salo (2016), Fridell et al. (2008), Gysel et al. (2017), Huang et al. (2018), Jeong et al. (2023), Lehtoranta et al. (2019), McCaffery et al. (2021), Moldanová et al. (2013), Peng et al. (2020), Timonen et al. (2017), Timonen et al. (2022), Winnes et al. (2020), Zetterdahl et al. (2016)
	NO	Celik et al. (2020), Diesch et al. (2013), Timonen et al. (2022), Zhao et al. (2020)
	NO_2	Celik et al. (2020), Diesch et al. (2013), Zhao et al. (2020)
	CO	Aakko-Saksa et al. (2016), Agrawal et al. (2008a), Agrawal et al. (2008b), Agrawal et al. (2010), Anderson et al. (2015a), Bai et al. (2020), Celik et al. (2020), Celo et al. (2015), Comer et al. (2017), Cooper et al. (1996), Cooper(2001) , Fridell and Salo (2016), Fridell et al. (2008) , Gysel et al. (2017), Huang et al. (2018), Lehtoranta et al. (2019), McCaffery et al. (2021), Moldanová et al. (2013), Peng et al. (2020), Timonen et al. (2017), Timonen et al. (2022), Winnes et al. (2020), Zetterdahl et al. (2016), Zhao et al. (2020)
	SO_2	Agrawal et al. (2008a), Agrawal et al. (2010), Bai et al. (2020), Celik et al. (2020), Comer et al. (2017), Diesch et al. (2013), Jeong et al. (2023), Lehtoranta et al. (2019), McCaffery et al. (2021), Moldanová et al. (2013), Timonen et al. (2022), Winnes et al. (2020), Zetterdahl et al. (2016), Zhao et al. (2020)
	NH_3	Aakko-Saksa et al. (2016), Aakko-Saksa et al. (2019), Cooper(2001), Timonen et al. (2017)
	CH_4	Aakko-Saksa et al. (2016), Anderson et al. (2015a), Comer et al. (2017), Cooper(2001), Lehtoranta et al. (2019), Peng et al. (2020), Timonen et al. (2017), Timonen et al. (2022), Winnes et al. (2020)
	NMVOC	Agrawal et al. (2008a), Agrawal et al. (2010), Cooper et al. (1996), Cooper(2001), Huang et al. (2018)
	O_3	Celik et al. (2020)
PARTICULATE PHASE	**PN**	Anderson et al. (2015a), Celik et al. (2020), Corbin et al. (2020), Diesch et al. (2013), Fridell and Salo (2016), Jeong et al. (2023), Kuittinen et al. (2021), Lack et al. (2009), Winnes et al. (2020), Zetterdahl et al. (2016), Zhao et al. (2020)
	Dmode	Corbin et al. (2020), Diesch et al. (2013), Jeong et al. (2023), Zetterdahl et al. (2016)
	PM_1	Celik et al. (2020), Diesch et al. (2013), Fridell et al. (2008) , Lack et al. (2009), Moldanová et al. (2013), Winnes et al. (2020), Zetterdahl et al. (2016)
	$PM_{2.5}$	Agrawal et al. (2008a), Agrawal et al. (2008b), Agrawal et al. (2010), Celo et al. (2015), Fridell et al. (2008), Gysel et al. (2017), Jeong et al. (2023), McCaffery et al. (2021), Moldanová et al. (2013), Peng et al. (2020)
	PM_{10}	Fridell et al. (2008), Moldanová et al. (2013)
	PM_{TOT}	Aakko-Saksa et al. (2016), Anderson et al. (2015a), Comer et al. (2017), Cooper(2001), Fridell et al. (2008), Gysel et al. (2017), Huang et al. (2018), Lehtoranta et al. (2019), Moldanová et al. (2013), Timonen et al. (2022), Winnes et al. (2020), Zetterdahl et al. (2016)
	BC	Aakko-Saksa et al. (2016), Agrawal et al. (2008a), Agrawal et al. (2008b), Agrawal et al. (2010), Anderson et al. (2015a), Celik et al. (2020), Celo et al. (2015), Comer et al. (2017), Corbin et al. (2020), Diesch et al. (2013), Fridell and Salo (2016), Jeong et al. (2023), Lack et al. (2009), Lanzafame et al. (2022), McCaffery et al. (2021), Peng et al. (2020), Timonen et al. (2017), Timonen et al. (2022), Zetterdahl et al. (2016), Zhao et al. (2020)
	OA	Celik et al. (2020), Diesch et al. (2013), Lack et al. (2009), Lanzafame et al. (2022), Timonen et al. (2022)
	SO_4^{2-}	Celik et al. (2020), Celo et al. (2015), Diesch et al. (2013), Huang et al. (2018), Jeong et al. (2023), Lack et al. (2009), Lanzafame et al., 2022, McCaffery et al. (2021), Timonen et al. (2022)
	NH_4^+	Celik et al. (2020), Lack et al. (2009), Lanzafame et al. (2022), Huang et al. (2018), Timonen et al. (2022)
	NO_3^-	Celik et al. (2020), Lack et al. (2009), Lanzafame et al. (2022), Huang et al. (2018), Timonen et al. (2022)
	Cl^-	Huang et al. (2018), Lanzafame et al. (2022), Timonen et al. (2022)

Table S10. Emission factors statistics for the 353 ship plumes identified during the campaign.

Mesured Quantity	Species	Unit	Temporal resolution	N_{plume}	Min	P10	P25	Median	Mean	P75	P90	Max	DL
PARTICULATE PHASE													
Particle number	PN	part.(kg fuel)$^{-1}$	10 sec	335	< DL	3.0E+15	4.2E+15	6.7E+15	8.1E+15	1.1E+16	1.5E+16	3.6E+16	4.5E+14
Particle masse concentration	$PM_{1\ (SMPS)}$	g.(kg fuel)$^{-1}$	2 min	236	< DL	< DL	< DL	1.0	1.6	2.3	4.0	9.8	0.4
	$PM_{1\ (OPC)}$	g.(kg fuel)$^{-1}$	1 min	342	< DL	< DL	0.2	0.5	0.9	1.1	2.0	8.5	0.1
	$PM_{2.5\ (OPC)}$	g.(kg fuel)$^{-1}$	1 min	341	< DL	< DL	< DL	0.5	1.0	1.3	2.5	8.4	0.3
	$PM_{10\ (OPC)}$	g.(kg fuel)$^{-1}$	1 min	341	< DL	< DL	< DL	0.6	1.2	1.6	3.3	9.2	0.5
Chemical Composition (PM_1)	BC	mg.(kg fuel)$^{-1}$	1 min	342	< DL	< DL	163	298	477	592	1 056	3 602	84
	Cl^-	mg.(kg fuel)$^{-1}$	30 sec	178	< DL	< DL	< DL	< DL	< DL	< DL	< DL	69.6	2.9
	NH_4^+	mg.(kg fuel)$^{-1}$	30 sec	178	< DL	< DL	< DL	< DL	10.1	16.6	31.6	96.0	5.0
	NO_3^-	mg.(kg fuel)$^{-1}$	30 sec	178	< DL	< DL	< DL	< DL	12.9	18.2	43.2	124.5	5.4
	OA	mg.(kg fuel)$^{-1}$	30 sec	178	< DL	355	543	863	1 872	1 742	4 044	25 445	153
	SO_4^{2-}	mg.(kg fuel)$^{-1}$	30 sec	178	< DL	< DL	< DL	50	175	174	567	2 002	28
GAS PHASE													
Nitrogen Oxides	NO_X	g.(kg fuel)$^{-1}$	10 sec	328	< DL	18.6	27.8	37.1	38.5	48.4	58.8	98.8	0.6
	NO	g.(kg fuel)$^{-1}$	10 sec	329	< DL	5.3	9.4	14.2	15.8	20.8	28.2	50.6	0.2
	NO_2	g.(kg fuel)$^{-1}$	10 sec	328	< DL	4.7	9.1	14.0	15.0	19.7	25.8	49.3	0.5
Carbon Oxides	CO	g.(kg fuel)$^{-1}$	10 sec	353	< DL	< DL	< DL	5.4	7.4	9.3	14.7	114.1	4.0
Sulfur Dioxide	SO_2	g.(kg fuel)$^{-1}$	10 sec	286	< DL	< DL	< DL	0.4	0.6	0.7	1.5	6.7	0.1
Ozone	O_3	g.(kg fuel)$^{-1}$	10 sec	279	< DL	-3.7	-7.5	-13.4	-14.8	-19.0	-26.8	-62.5	0.6
Ammoniac	NH_3	g.(kg fuel)$^{-1}$	10 sec	51	< DL	< DL	< DL	< DL	< DL	< DL	< DL	0.2	0.1
Volatils Organics Compounds (VOC)	CH_4	g.(kg fuel)$^{-1}$	10 sec	353	< DL	< DL	< DL	0.4	1.3	1.0	2.9	23.4	0.3
	$(CH_2O_2)H^+$	mg.(kg fuel)$^{-1}$	10 sec	132	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	138
	$(CH_3OH)H^+$	mg.(kg fuel)$^{-1}$	10 sec	132	< DL	< DL	< DL	< DL	< DL	< DL	< DL	869	182
	$(C_2H_4O)H^+$	mg.(kg fuel)$^{-1}$	10 sec	132	< DL	< DL	< DL	< DL	< DL	< DL	< DL	1 093	137
	$(C_2H_4O_2)H^+$	mg.(kg fuel)$^{-1}$	10 sec	132	< DL	< DL	< DL	< DL	< DL	< DL	< DL	1 981	275
	$(C_2H_6O)H^+$	mg.(kg fuel)$^{-1}$	10 sec	131	< DL	< DL	< DL	< DL	< DL	< DL	< DL	1 040	89
	$(C_2H_6S)H^+$	mg.(kg fuel)$^{-1}$	10 sec	132	< DL	< DL	< DL	< DL	6	< DL	< DL	755	4
	$(C_3H_6)H^+$	mg.(kg fuel)$^{-1}$	10 sec	131	< DL	< DL	< DL	< DL	< DL	< DL	< DL	575	87
	$(C_3H_6O)H^+$	mg.(kg fuel)$^{-1}$	10 sec	132	< DL	< DL	< DL	< DL	< DL	< DL	< DL	915	128
	$(C_3H_6O_2)H^+$	mg.(kg fuel)$^{-1}$	10 sec	131	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	46
	$(C_4H_{10}O_3)H^+$	mg.(kg fuel)$^{-1}$	10 sec	132	< DL	< DL	< DL	< DL	< DL	< DL	< DL	269	29
	$(C_4H_{12}O_2)H^+$	mg.(kg fuel)$^{-1}$	10 sec	132	< DL	< DL	< DL	< DL	< DL	< DL	< DL	48	33
	$(C_4H_6O)H^+$	mg.(kg fuel)$^{-1}$	10 sec	132	< DL	< DL	< DL	< DL	< DL	< DL	< DL	121	23
	$(C_4H_8)H^+$	mg.(kg fuel)$^{-1}$	10 sec	132	< DL	< DL	< DL	< DL	< DL	< DL	< DL	1 474	147
	$(C_4H_8O)H^+$	mg.(kg fuel)$^{-1}$	10 sec	132	< DL	< DL	< DL	< DL	< DL	< DL	< DL	124	31
	$(C_4H_8O_2)H^+$	mg.(kg fuel)$^{-1}$	10 sec	132	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	31
	$(C_5H_{10})H^+$	mg.(kg fuel)$^{-1}$	10 sec	131	< DL	< DL	< DL	< DL	< DL	< DL	< DL	282	44
	$(C_5H_{10}O)H^+$	mg.(kg fuel)$^{-1}$	10 sec	131	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	40
	$(C_5H_8)H^+$	mg.(kg fuel)$^{-1}$	10 sec	132	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	46
	$(C_5H_8O_2)H^+$	mg.(kg fuel)$^{-1}$	10 sec	132	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	31
	$(C_6H_{10})H^+$	mg.(kg fuel)$^{-1}$	10 sec	132	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	32
	$(C_6H_{10}O)H^+$	mg.(kg fuel)$^{-1}$	10 sec	131	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	26
	$(C_6H_{12})H^+$	mg.(kg fuel)$^{-1}$	10 sec	132	< DL	< DL	< DL	< DL	< DL	< DL	< DL	166	34
	$(C_6H_{12}O)H^+$	mg.(kg fuel)$^{-1}$	10 sec	132	< DL	< DL	< DL	< DL	< DL	< DL	< DL	308	28
	$(C_6H_{12}O_2)H^+$	mg.(kg fuel)$^{-1}$	10 sec	132	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	14
	$(C_6H_6)H^+$	mg.(kg fuel)$^{-1}$	10 sec	132	< DL	< DL	< DL	< DL	< DL	< DL	< DL	82	37
	$(C_7H_{12})H^+$	mg.(kg fuel)$^{-1}$	10 sec	131	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	32
	$(C_7H_8)H^+$	mg.(kg fuel)$^{-1}$	10 sec	132	< DL	< DL	< DL	< DL	< DL	< DL	108	1 347	80
	$(C_8H_{10})H^+$	mg.(kg fuel)$^{-1}$	10 sec	132	< DL	< DL	< DL	< DL	201	176	460	7 598	122
	$(C_8H_{14})H^+$	mg.(kg fuel)$^{-1}$	10 sec	131	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	33
	$(C_8H_8)H^+$	mg.(kg fuel)$^{-1}$	10 sec	131	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	25
	$(C_9H_{12})H^+$	mg.(kg fuel)$^{-1}$	10 sec	132	< DL	< DL	< DL	< DL	< DL	< DL	< DL	525	42
	$(C_9H_{18}O)H^+$	mg.(kg fuel)$^{-1}$	10 sec	132	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	28
	$(C_{10}H_{14})H^+$	mg.(kg fuel)$^{-1}$	10 sec	132	< DL	< DL	< DL	< DL	< DL	< DL	< DL	118	29
	$(C_{10}H_{14}O)H^+$	mg.(kg fuel)$^{-1}$	10 sec	132	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	15
	$(C_{10}H_{16})H^+$	mg.(kg fuel)$^{-1}$	10 sec	132	< DL	< DL	< DL	< DL	< DL	< DL	< DL	145	56
	$(C_{10}H_{16}O)H^+$	mg.(kg fuel)$^{-1}$	10 sec	131	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	19
	$(C_{10}H_{18})H^+$	mg.(kg fuel)$^{-1}$	10 sec	132	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	19
	$(C_{11}H_{16})H^+$	mg.(kg fuel)$^{-1}$	10 sec	132	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	8
	$(C_{11}H_{18})H^+$	mg.(kg fuel)$^{-1}$	10 sec	131	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	20
	$(C_{11}H_{20})H^+$	mg.(kg fuel)$^{-1}$	10 sec	132	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	17
	$(C_{12}H_{20})H^+$	mg.(kg fuel)$^{-1}$	10 sec	131	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	25

Note: The number of plumes for which compounds were quantified using HR-ToF-AMS analyzers (OA, SO_4^{2-}, NH_4^+ et Cl^-) and PTR-ToF-MS (NMVOCs such as $C_8H_{10}H^+$) is nearly half that of other species due to the exclusive deployment of these analyzers at the PEB station.

Table S11. Emission factors statistics categorized by operational phase for the 353 ship plumes identified during the campaign.

Mesured Quantity	Species	Unit	Time resolution	Operating phase	N_{plume}	Min	P10	P25	Median	Mean	P75	P90	Max	DL
PARTICULATE PHASE														
Particle number	PN	part.(kg fuel)$^{-1}$	10 sec	At berth	115	3.5E+15	6.2E+15	7.9E+15	9.9E+15	1.0E+16	1.2E+16	1.5E+16	2.9E+16	4.5E+14
				Manoeuvring	44	9.0E+14	2.9E+15	3.6E+15	5.6E+15	6.5E+15	9.2E+15	1.1E+16	2.1E+16	4.5E+14
				Navigation	161	< DL	2.7E+15	3.3E+15	4.9E+15	6.9E+15	8.7E+15	1.5E+16	3.6E+16	4.5E+14
				Mixed phase	15	2.3E+15	3.2E+15	4.2E+15	5.9E+15	7.9E+15	9.3E+15	1.5E+16	2.4E+16	4.5E+14
Particle masse concentration	$PM_{1\ (SMPS)}$	g.(kg fuel)$^{-1}$	2 min	At berth	89	< DL	< DL	< DL	0.6	0.5	0.9	1.1	2.9	0.4
				Manoeuvring	27	< DL	< DL	< DL	1.1	1.1	1.7	2.6	2.7	0.4
				Navigation	110	< DL	< DL	1.1	2.0	2.4	3.6	5.0	9.8	0.4
				Mixed phase	10	< DL	0.7	1.2	3.3	3.3	4.7	5.3	8.3	0.4
	$PM_{1\ (OPC)}$	g.(kg fuel)$^{-1}$	1 min	At berth	114	< DL	< DL	0.1	0.2	0.3	0.4	0.6	4.6	0.1
				Manoeuvring	46	< DL	< DL	0.2	0.7	1.2	1.1	3.0	6.4	0.1
				Navigation	166	< DL	0.3	0.4	0.6	1.1	1.5	2.3	8.5	0.1
				Mixed phase	16	< DL	< DL	0.6	1.4	1.6	1.9	3.0	6.4	0.1
	$PM_{2.5\ (OPC)}$	g.(kg fuel)$^{-1}$	1 min	At berth	114	< DL	< DL	< DL	< DL	0.3	0.4	0.7	5.8	0.3
				Manoeuvring	46	< DL	< DL	0.4	0.7	1.2	1.3	3.0	6.5	0.3
				Navigation	165	< DL	< DL	0.3	0.8	1.3	1.8	2.9	8.4	0.3
				Mixed phase	16	< DL	< DL	0.7	1.9	1.8	2.1	3.1	6.5	0.3
	$PM_{10\ (OPC)}$	g.(kg fuel)$^{-1}$	1 min	At berth	113	< DL	< DL	< DL	< DL	< DL	0.6	1.0	6.2	0.5
				Manoeuvring	46	< DL	< DL	< DL	0.7	1.4	1.7	3.9	8.9	0.5
				Navigation	166	< DL	< DL	< DL	1.0	1.5	2.2	3.5	9.2	0.5
				Mixed phase	16	< DL	< DL	1.1	2.0	2.1	2.9	3.6	5.7	0.5
Chemical Composition (PM_1)	BC	mg.(kg fuel)$^{-1}$	1 min	At berth	114	< DL	< DL	105	165	196	247	318	2 080	84
				Manoeuvring	45	< DL	112	207	436	637	683	1 286	3 602	84
				Navigation	167	< DL	< DL	268	477	594	791	1 226	3 254	84
				Mixed phase	16	136	185	380	796	806	1 063	1 278	2 200	84
	Cl^-	mg.(kg fuel)$^{-1}$	30 sec	At berth	91	< DL	< DL	< DL	< DL	< DL	< DL	< DL	37	2.9
				Manoeuvring	12	< DL	< DL	< DL	< DL	< DL	< DL	3	13	2.9
				Navigation	66	< DL	< DL	< DL	< DL	< DL	< DL	< DL	70	2.9
				Mixed phase	9	< DL	< DL	< DL	< DL	3	< DL	10	19	2.9
	NH_4^+	mg.(kg fuel)$^{-1}$	30 sec	At berth	91	< DL	< DL	< DL	< DL	< DL	< DL	21	41	5.0
				Manoeuvring	12	< DL	< DL	< DL	< DL	15	31	40	45	5.0
				Navigation	66	< DL	< DL	< DL	< DL	15	22	54	96	5.0
				Mixed phase	9	< DL	< DL	11	30	23	36	41	41	5.0
	NO_3^-	mg.(kg fuel)$^{-1}$	30 sec	At berth	91	< DL	< DL	< DL	< DL	6	9	23	67	5.4
				Manoeuvring	12	< DL	< DL	< DL	< DL	15	23	48	67	5.4
				Navigation	66	< DL	< DL	< DL	< DL	18	32	56	123	5.4
				Mixed phase	9	< DL	< DL	18	22	37	29	103	125	5.4
	OA	mg.(kg fuel)$^{-1}$	30 sec	At berth	91	< DL	334	470	611	658	799	950	2 538	153
				Manoeuvring	12	< DL	181	487	861	969	1 394	1 986	2 237	153
				Navigation	66	< DL	752	1 250	2 247	3 716	4 301	6 626	25 445	153
				Mixed phase	9	429	759	1 137	2 164	1 827	2 371	2 692	3 177	153
	SO_4^{2-}	mg.(kg fuel)$^{-1}$	30 sec	At berth	91	< DL	< DL	< DL	< DL	33	50	80	289	28
				Manoeuvring	12	< DL	< DL	< DL	< DL	58	120	149	190	28
				Navigation	66	< DL	< DL	75	235	390	580	944	2 002	28
				Mixed phase	9	< DL	53	87	182	189	270	351	365	28
GAS PHASE														
Nitrogen Oxides	NO_X	g.(kg fuel)$^{-1}$	10 sec	At berth	114	< DL	21.2	29.4	40.0	39.8	50.8	58.3	78.3	0.6
				Manoeuvring	45	3.7	14.4	23.1	33.5	36.3	44.8	65.0	98.8	0.6
				Navigation	155	< DL	17.3	28.0	36.2	38.3	48.2	61.8	97.8	0.6
				Mixed phase	14	14.7	26.1	30.9	39.1	38.3	46.5	52.9	59.2	0.6
	NO	g.(kg fuel)$^{-1}$	10 sec	At berth	114	< DL	6.9	11.0	15.9	16.6	22.1	27.4	38.1	0.2
				Manoeuvring	45	0.5	5.2	8.0	14.3	15.9	19.2	31.0	41.6	0.2
				Navigation	155	< DL	4.4	8.8	12.3	15.1	19.4	30.1	50.6	0.2
				Mixed phase	15	5.9	12.5	13.1	16.2	16.4	19.9	22.4	25.0	0.2
	NO_2	g.(kg fuel)$^{-1}$	10 sec	At berth	114	< DL	5.9	10.0	14.6	15.2	19.2	25.7	48.2	0.5
				Manoeuvring	45	< DL	3.3	4.9	9.9	12.6	19.0	23.7	41.0	0.5
				Navigation	155	< DL	5.3	10.4	15.1	15.8	20.5	26.5	49.3	0.5
				Mixed phase	14	1.4	5.4	7.6	12.9	13.7	20.0	22.5	28.7	0.5

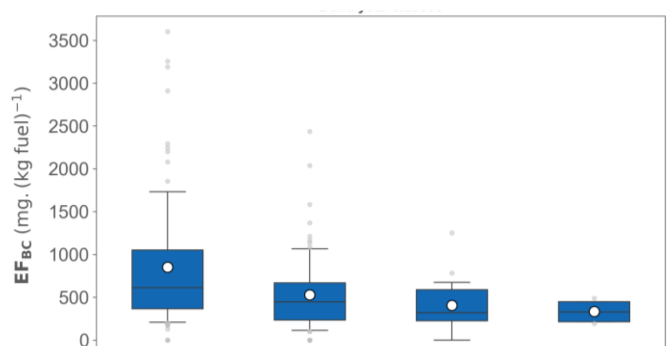
Mesured Quantity	Species	Unit	Time resolution	Operating phase	N_{plume}	Min	P10	P25	Median	Mean	P75	P90	Max	DL
Carbon Oxides	CO	g.(kg fuel)$^{-1}$	10 sec	At berth	118	< DL	< DL	< DL	< DL	< DL	5.4	7.1	27.9	4.0
				Manoeuvring	46	< DL	< DL	< DL	7.1	8.3	12.1	16.9	46.5	4.0
				Navigation	173	< DL	< DL	< DL	7.2	9.8	10.9	17.9	114.1	4.0
				Mixed phase	16	< DL	< DL	4.9	8.6	7.3	10.7	11.8	13.2	4.0
Sulfur Dioxide	SO_2	g.(kg fuel)$^{-1}$	10 sec	At berth	94	< DL	< DL	< DL	0.4	0.4	0.6	1.0	2.1	0.1
				Manoeuvring	43	< DL	< DL	0.2	0.4	0.9	1.5	2.4	4.3	0.1
				Navigation	136	< DL	< DL	< DL	0.4	0.6	0.6	1.5	5.9	0.1
				Mixed phase	13	< DL	< DL	0.2	0.7	1.5	1.8	3.9	6.7	0.1
Ozone	O_3	g.(kg fuel)$^{-1}$	10 sec	At berth	103	< DL	-4.1	-6.8	-13.4	-13.8	-18.6	-23.8	-45.7	0.6
				Manoeuvring	37	-2.5	-4.2	-6.5	-9.8	-12.5	-13.6	-23.3	-50.3	0.6
				Navigation	126	< DL	-3.5	-10.0	-14.5	-16.5	-21.7	-27.9	-62.5	0.6
				Mixed phase	13	-1.4	-4.1	-5.7	-13.3	-12.7	-16.7	-18.3	-35.8	0.6
Ammoniac	NH_3	g.(kg fuel)$^{-1}$	10 sec	At berth	24	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	0.1
				Manoeuvring	3	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	0.1
				Navigation	20	< DL	< DL	< DL	< DL	< DL	< DL	< DL	0.2	0.1
				Mixed phase	4	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	0.1
Volatils Organics Compounds (VOC)	CH_4	g.(kg fuel)$^{-1}$	10 sec	At berth	118	< DL	< DL	< DL	0.6	1.9	1.7	4.5	23.4	0.3
				Manoeuvring	46	< DL	< DL	< DL	0.4	1.7	1.9	4.3	15.8	0.3
				Navigation	173	< DL	< DL	< DL	0.3	0.6	0.7	1.4	10.4	0.3
				Mixed phase	16	< DL	< DL	< DL	0.3	2.1	0.7	7.3	15.2	0.3
	$(CH_2O_2)H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	138
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	138
				Navigation	54	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	138
				Mixed phase	10	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	138
	$(CH_3OH)H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	869	182
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	316	426	621	182
				Navigation	54	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	182
				Mixed phase	10	< DL	< DL	< DL	< DL	< DL	< DL	< DL	829	182
	$(C_2H_4O)H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	821	137
				Manoeuvring	9	< DL	< DL	< DL	< DL	153	< DL	447	1 093	137
				Navigation	54	< DL	< DL	< DL	< DL	< DL	< DL	< DL	216	137
				Mixed phase	10	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	137
	$(C_2H_4O_2)H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	1 733	275
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	< DL	< DL	466	275
				Navigation	54	< DL	< DL	< DL	< DL	< DL	< DL	< DL	1 981	275
				Mixed phase	10	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	275
	$(C_2H_6O)H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	911	89
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	< DL	235	390	89
				Navigation	53	< DL	< DL	< DL	< DL	< DL	< DL	< DL	1 040	89
				Mixed phase	10	< DL	< DL	< DL	< DL	< DL	94	221	271	89
	$(C_2H_6S)H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	4
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	4
				Navigation	54	< DL	< DL	< DL	< DL	14	< DL	< DL	755	4
				Mixed phase	10	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	4
	$(C_3H_6)H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	575	87
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	87
				Navigation	53	< DL	< DL	< DL	< DL	< DL	< DL	< DL	103	87
				Mixed phase	10	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	87
	$(C_3H_6O)H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	915	128
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	< DL	< DL	348	128
				Navigation	54	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	128
				Mixed phase	10	< DL	< DL	< DL	< DL	< DL	< DL	201	277	128
	$(C_3H_6O_2)H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	46
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	46
				Navigation	53	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	46
				Mixed phase	10	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	46
	$(C_4H_{10}O_3)H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	269	29
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	< DL	< DL	41	29
				Navigation	54	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	29
				Mixed phase	10	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	29

Mesured Quantity	Species	Unit	Time resolution	Operating phase	N_{plume}	Min	P10	P25	Median	Mean	P75	P90	Max	DL
Volatils Organics Compounds (VOC)	$(C_4H_{12}O_2)H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	48	33
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	33
				Navigation	54	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	33
				Mixed phase	10	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	33
	$(C_4H_6O)H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	23
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	< DL	24	121	23
				Navigation	54	< DL	< DL	< DL	< DL	< DL	< DL	< DL	36	23
				Mixed phase	10	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	23
	$(C_4H_8)H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	147
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	147
				Navigation	54	< DL	< DL	< DL	< DL	< DL	< DL	< DL	1 474	147
				Mixed phase	10	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	147
	$(C_4H_8O)H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	31
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	< DL	< DL	124	31
				Navigation	54	< DL	< DL	< DL	< DL	< DL	< DL	< DL	86	31
				Mixed phase	10	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	31
	$(C_4H_8O_2)H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	31
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	31
				Navigation	54	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	31
				Mixed phase	10	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	31
	$(C_5H_{10})H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	44
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	< DL	56	282	44
				Navigation	53	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	44
				Mixed phase	10	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	44
	$(C_5H_{10}O)H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	40
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	40
				Navigation	53	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	40
				Mixed phase	10	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	40
	$(C_5H_8)H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	46
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	46
				Navigation	54	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	46
				Mixed phase	10	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	46
	$(C_5H_8O_2)H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	31
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	31
				Navigation	54	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	31
				Mixed phase	10	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	31
	$(C_6H_{10})H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	32
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	32
				Navigation	54	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	32
				Mixed phase	10	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	32
	$(C_6H_{10}O)H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	26
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	26
				Navigation	53	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	26
				Mixed phase	10	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	26
	$(C_6H_{12})H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	34
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	< DL	< DL	166	34
				Navigation	54	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	34
				Mixed phase	10	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	34
	$(C_6H_{12}O)H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	308	28
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	28
				Navigation	54	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	28
				Mixed phase	10	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	28
	$(C_6H_{12}O_2)H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	14
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	14
				Navigation	54	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	14
				Mixed phase	10	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	14
	$(C_6H_6)H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	37
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	37
				Navigation	54	< DL	< DL	< DL	< DL	< DL	< DL	< DL	82	37
				Mixed phase	10	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	37

Mesured Quantity	Species	Unit	Time resolution	Operating phase	N_{plume}	Min	P10	P25	Median	Mean	P75	P90	Max	DL
Volatils Organics Compounds (VOC)	$(C_7H_{12})H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	32
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	32
				Navigation	53	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	32
				Mixed phase	10	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	32
	$(C_7H_8)H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	94	800	80
				Manoeuvring	9	< DL	< DL	< DL	< DL	183	191	442	1 108	80
				Navigation	54	< DL	< DL	< DL	< DL	< DL	< DL	< DL	1 347	80
				Mixed phase	10	< DL	< DL	< DL	< DL	< DL	< DL	190	473	80
	$(C_8H_{10})H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	335	291	669	7 598	122
				Manoeuvring	9	< DL	< DL	< DL	< DL	143	257	370	466	122
				Navigation	54	< DL	< DL	< DL	< DL	< DL	< DL	284	937	122
				Mixed phase	10	< DL	< DL	< DL	< DL	< DL	217	333	359	122
	$(C_8H_{14})H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	33
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	33
				Navigation	53	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	33
				Mixed phase	10	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	33
	$(C_8H_8)H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	25
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	25
				Navigation	53	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	25
				Mixed phase	10	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	25
	$(C_9H_{12})H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	52	525	42
				Manoeuvring	9	< DL	< DL	< DL	< DL	50	< DL	165	327	42
				Navigation	54	< DL	< DL	< DL	< DL	< DL	< DL	< DL	151	42
				Mixed phase	10	< DL	< DL	< DL	< DL	< DL	< DL	< DL	107	42
	$(C_9H_{18}O)H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	28
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	28
				Navigation	54	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	28
				Mixed phase	10	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	28
	$(C_{10}H_{14})H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	118	29
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	< DL	< DL	75	29
				Navigation	54	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	29
				Mixed phase	10	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	29
	$(C_{10}H_{14}O)H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	15
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	15
				At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	15
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	15
	$(C_{10}H_{16})H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	145	56
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	56
				At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	145	56
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	56
	$(C_{10}H_{16}O)H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	19
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	19
				At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	19
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	19
	$(C_{10}H_{18})H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	19
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	19
				At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	19
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	19
	$(C_{11}H_{16})H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	8
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	8
				Navigation	54	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	8
				Mixed phase	10	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	8
	$(C_{11}H_{18})H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	20
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	20
				Navigation	53	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	20
				Mixed phase	10	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	20
	$(C_{11}H_{20})H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	17
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	17
				Navigation	54	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	17
				Mixed phase	10	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	17
	$(C_{12}H_{20})H^+$	mg.(kg fuel)$^{-1}$	10 sec	At berth	59	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	25
				Manoeuvring	9	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	25
				Navigation	53	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	25
				Mixed phase	10	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	25

Table S12. Potential hypotheses for elevated methane emission factors in the study area

N°	Hypothesis details
1	Some plumes may originate from multiple ships of the same category, particularly "at berth" ships. In such cases, one ship might be using a hybrid engine running on both fuel (fuel oil and LNG), or an engine operating on natural gas or LNG, which could elevate the emission factor without reaching the levels typically associated with LNG-powered ships. This scenario is most plausible for the EFs observed from "at berth." cruise ships, which often consist of several vessels
2	Capture of emissions at engine starts-up, where incomplete combustion could result in higher CH_4 emissions. However, the lack of correlation between CH_4 and CO (a known tracer of incomplete combustion (Latarche, 2021)) does not support this hypothesis.
3	A GTL (liquefied methane gas) pilot boat that routinely accompanies ships entering or leaving the port could also contribute to the observed EFs. This boat operates from the channel entrance to the berth and vice versa. Thus, one likely explanation for higher EFs for ships in "manoeuvring/navigation" is the simultaneous measurement of emissions from both the ship and pilot boat. In this case, the CH_4 emission factor calculated underestimates CH_4 emissions from the pilot boat because concentrations are related to the combined CO_2 emissions of both the ship and the pilot boat (dominated by the ship). Conversely, this calculation overestimates the EF_{CH4} for the ship alone.
4	Diffuse oceanic emissions of CH_4 from ships in "manoeuvring/navigation" was also considered due to the shallow seabed near the measurement stations (less than 10 m (Pairaud et al., 2011)), as well as water temperature and weather conditions at this time of year. Specific studies on methane emitted by oceans show that diffuse oceanic emissions close to the coasts (<2,000 m) contribute to the greatest diffusive flux of methane due to surface water supersaturation (Vogt et al., 2023). This supersaturation is linked both to emissions from the ocean floor and methanogenesis of the microbial cycle of organic matter compounds dissolved in water, particularly DMS (Weber et al., 2019). The stirring up of the water by passing ships could increase these diffuse emissions. However, the absence of DMS in plumes with higher CH_4 levels does not support this hypothesis.



	Tier 0	Tier I	Tier II	Tier III
NSP*	89	79	15	4
NQP**	86	76	15	4
TDQP***	13	17	2	0
NDVQP****	17	19	5	4

* NSP: Number of plumes studied - ** NQP: Number of quantified plumes - *** TDQP: Total duration of quantified plumes (hours)
**** NDVQP: Number of different vessels in the quantified plumes

Figure S8. EF_{BC} distribution as a function of Tier regulations imposed by the MARPOL Convention. For each box plot, the coloured box represents the interquartile range between the 25th percentile (P25) and the 75th percentile (P75), the vertical error bar represents the interval between the 10th percentile (P10) and the 90th percentile (P90), the black horizontal line represents the median, the white circle represents the mean and the grey dots represent the extremes.

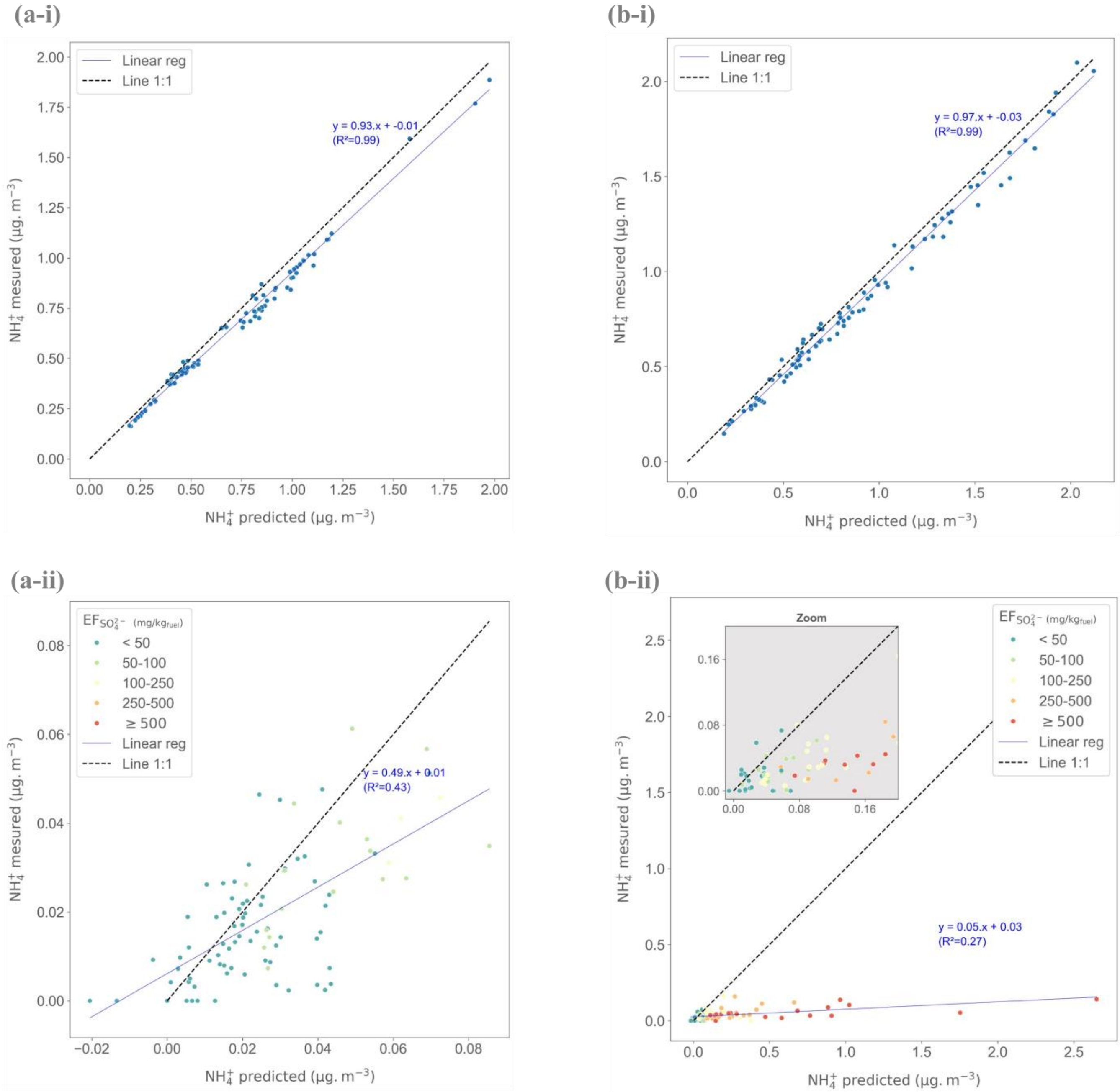


Figure S9. Correlation between NH_4 measured and NH_4 predicted to evaluate the ion balance or neutralisation of the aerosol for (a) ships "at berth" and (b) ships "manoeuvring/navigation" during (i) the periods defining the background noise before and after each plume and (ii) the duration of the plumes (each point is coloured according to the sulphate emission factor of the plume considered).

Table S13. Metals - additional concentrations and contribution from shipping in plumes by operating phases. The 25th and 75th percentiles are indicated for each median value and are presented as follows median [25th percentile / 75th percentile].

Measured Quantity	Species	units	Operating phase	N_{plumes} (1)	Additional concentrations from shipping(2)	Relative contribution of shipping(3)
Metals Composition (PM_1)	Ca	$ng.m^{-3}$	At berth	22	<DL [<DL / <DL]	- [- / -]
			In Manoeuvring/Navigation (arrival)	27	<DL [<DL / 2.5]	- [- / 3.7%]
			In Manoeuvring/Navigation (departure)	20	<DL [<DL / 4.3]	- [- / 12.2%]
	Fe	$ng.m^{-3}$	At berth	22	<DL [<DL / <DL]	- [- / -]
			In Manoeuvring/Navigation (arrival)	27	2.4 [<DL / 4.7]	11.2% [- / 31.2%]
			In Manoeuvring/Navigation (departure)	20	1.2 [<DL / 3.8]	5.2% [- / 16.2%]
	K	$ng.m^{-3}$	At berth	22	<DL [<DL / 1.5]	- [- / 9.5%]
			In Manoeuvring/Navigation (arrival)	27	<DL [<DL / 3.0]	- [- / 15.7%]
			In Manoeuvring/Navigation (departure)	20	<DL [<DL / 2.0]	- [- / 10.8%]
	Ni	$ng.m^{-3}$	At berth	22	<DL [<DL / <DL]	- [- / -]
			In Manoeuvring/Navigation (arrival)	27	4.4 [0.4 / 7.5]	86.4% [10.8% / 94.3%]
			In Manoeuvring/Navigation (departure)	20	2.1 [0.6 / 3.0]	67.5% [23.5% / 91.1%]
	V	$ng.m^{-3}$	At berth	22	<DL [<DL / <DL]	- [- / -]
			In Manoeuvring/Navigation (arrival)	27	1.9 [0.4 / 8.5]	71.8% [12.7% / 93.8%]
			In Manoeuvring/Navigation (departure)	20	1.3 [0.3 / 2.1]	58.1% [39.4% / 84.8%]
	Zn	$ng.m^{-3}$	At berth	22	<DL [<DL / <DL]	- [- / -]
			In Manoeuvring/Navigation (arrival)	27	<DL [<DL / 1.0]	- [- / 13%]
			In Manoeuvring/Navigation (departure)	20	<DL [<DL / 0.1]	- [- / 0.8%]

(1) N_{plumes} represents the total number of plumes used as the basis for the statistical calculations; (2) statistics from the average excess concentration of each plume; (3) statistics from the relative contribution of each plume, relative to global concentrations; (4) Below detection limit (<DL).

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