

Supplementary file

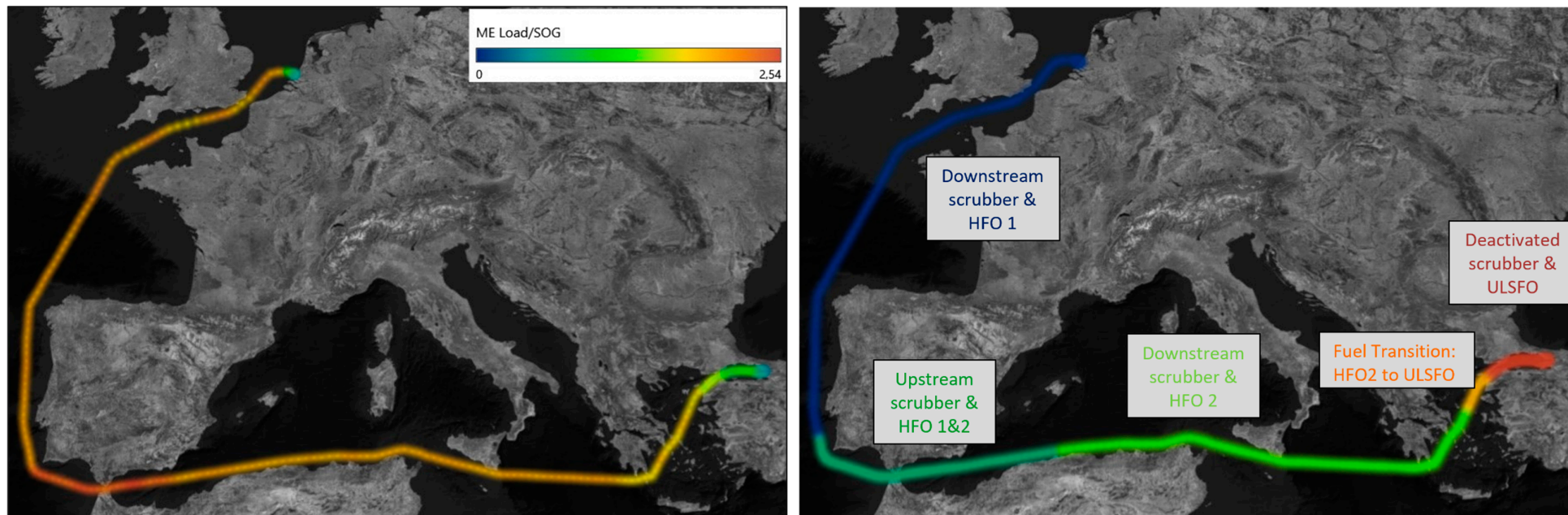


Figure S1. Map designates the ship's voyage and the colour rendering of mean load (in %) of the main engine and speed over ground (in knots) ratio (left). Map illustrates the geographical locations of each fuel used and the two changeover processes during the voyage (right).

Table S1. Mean NO_x, SO₂, CO and THC emission levels (in g/kg fuel) and standard deviation for different sampling points, fuel types, mean load (in %) of the main engine and specific fuel oil consumption (in g fuel/kWh)

Fuel	Sampling point	Engine Load (%)	SFOC (g fuel/kWh)	Emission Level (g/kg fuel)			
				NO _x	SO ₂	CO	THC
HFO1	Downstream	33.6	184.7	94.9±1.88	7.93±0.484	1.89±0.0820	0.483±0.0227
HFO1	Downstream	37.3	183.1	-	-	-	0.445±0.0152
HFO1	Downstream	37.0	183.5	92.7±1.66	8.93±0.930	1.97±0.0799	-
HFO1&2	Downstream	40.5	183.3	-	-	-	0.371±0.0509
HFO1&2	Upstream	36.9	183.6	85.6±2.93	31.8±2.18	2.01±0.0541	-
HFO1&2	Upstream	36.6	183.7	-	-	-	0.364±0.0215
HFO2	Downstream	32.1	185.4	81.5±4.95	6.14±1.91	3.08±0.629	0.416±0.0178
ULSFO	Deactivated	11.4	202.6	81.9±9.31	1.56±0.702	2.75±0.523	0.588±0.0741

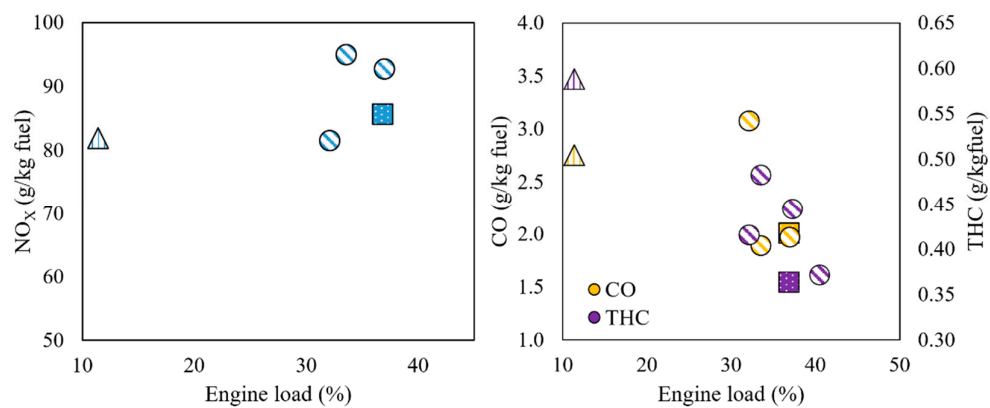


Figure S2. Mean emission levels (in g/kg fuel) for NO_x (left) and CO and THC (right) in relation to engine load (in %) for the different sampling points. Squares correspond to upstream of the scrubber with HFO, circles correspond to downstream of the scrubber and HFO and triangles to deactivated scrubber with ULSFO.

Table S2. Mean PN emission levels (in #/kg fuel) and standard deviation (and number of individual values in parenthesis) for different sampling points, fuel types, sampling scheme (layout, dilution, temperature), mean load (in %) of the main engine and specific fuel oil consumption (in g fuel/kWh)

Fuel	Sampling point	Layout	Dilution	Dilution Temperature (°C)	Engine load (%)	SFOC (g fuel/kWh)	PN (#/kg fuel)
HFO1	Downstream	Fresh	25	250	36.5±0.139 (2)	183.8±0.268 (2)	9.55E+15 ± 3.44E+13 (16)
HFO1&2	Upstream	Fresh	100	250	37.2±0.329 (4)	183.9±0.783 (4)	4.67E+14 ± 3.24E+13 (70)
HFO1&2	Upstream	Fresh	40	250	37.4±0.163 (4)	183.3±0.149 (4)	5,70E+14 ± 8.83E+13 (66)
HFO1&2	Upstream	Thermodenuder	40	150	36.7±0.178 (3)	183.2±0.685 (3)	2.71E+14 ± 9.94E+13 (36)
HFO1&2	Upstream	Fresh	40	150	36.5±0.0537 (3)	183.8±0.167 (3)	1.50E+14 ± 1.17E+13 (60)
HFO1&2	Upstream	Catalytic Stripper+ Ejector Diluter	60	150	36.6±0.0276 (3)	183.7±0.139 (3)	9.78E+15 ± 2.96E+14 (46)
HFO2	Downstream	Fresh	25	250	29.3±0.462 (3)	186.3±0.500 (3)	1.03E+15 ± 2.03E+13 (30)
HFO2	Downstream	Catalytic Stripper+ Ejector Diluter	90	250	31.7±1.84 (2)	185.3±0.306 (2)	6.31E+14 ± 1.17E+13 (24)
HFO2	Downstream	Thermodenuder	25	250	31.9±1.68 (2)	185.4±0.371 (2)	1.14E+15 ± 5.21E+13 (29)

Fuel	Sampling point	Layout	Dilution	Dilution Temperature (°C)	Engine load (%)	SFOC (g fuel/kWh)	PN (#/kg fuel)
HFO2	Downstream	Fresh	25	250	29.7±0.594 (3)	185.6±1.00 (3)	1.01E+15 ± 7.45E+13 (42)
Fuel transition HFO2-ULSFO	Deactivated	Fresh	25	250	23.0±4.03 (3)	193.0±7.69 (3)	1.07E+15 ± 8.44E+14 (48)
ULSFO	Deactivated	Fresh	25	250	10.6±0.0190 (2)	202.9±0.357 (2)	2.19E+14 ± 6.48E+13 (32)
ULSFO	Deactivated	Fresh	25	250	10.8±0.126 (3)	200.6±3.12 (3)	1.53E+14 ± 7.28E+12 (46)
ULSFO	Deactivated	Thermodenuder	25	250	11.6 (1)	200.3 (1)	1.54E+14 ± 3.30E+12 (22)
ULSFO	Deactivated	Catalytic Stripper+ Ejector Diluter	60	250	12.0±0.309 (3)	199.7±0.469 (3)	1.11E+14 ± 2.22E+13 (24)