

General comments

The manuscript presents a timely and policy-relevant study that quantifies shipping emission factors and apportions organic aerosol sources in Toulon, France, a coastal port city. The authors report detailed EFs for a wide range of pollutants, including SO₂, NO_x, CO, CH₄, black carbon, organics, PAHs, and particle number concentrations. By distinguishing EFs across vessel types and operational modes (e.g., arrivals vs. departures), and comparing results to pre-regulation studies, the work offers clear evidence of the evolving impact of marine fuel regulations on air quality. The ability to resolve vessel-specific EFs and link them to auxiliary engine power, fuel type, and plume characteristics is a notable strength of the study and represents a valuable dataset for emission inventory improvement and regulatory evaluation. The integration of detailed HR-ToF-AMS measurements with Positive Matrix Factorization factors that distinguish between road- and shipping-related emissions of hydrocarbons represent a valuable and novel contribution to the field by particularly in light of the IMO2020 regulation and the forthcoming SECA Med implementation.

That said, the manuscript would benefit substantially from a comprehensive round of language editing, as many sentences could be rewritten for clarity, conciseness, and smoother flow. The readability of the manuscript would benefit from the consistent use of the Oxford comma, which helps to clarify lists and prevent ambiguity. Additionally, contractions (e.g., “don’t” in Line 152) should be avoided in formal scientific writing to maintain a professional tone throughout the text. Section 3.2 would benefit from more direct references to the figures to help guide the reader through the results. Currently, the discussion lacks clear connections to the visual data, which makes it difficult to follow the interpretation and significance of the findings. Overall, the study is technically sound and presents novel results, but significant editorial revision is needed to ensure the presentation matches the quality of the science.

Specific Comments

Lines 186-188. “The pie chart representing the median PM1 chemical composition shows the following proportions: 53 % organics, 16 % sulfate, 7 % ammonium, 2 % nitrate and 21 % BC.”

Could you provide the standard deviations to provide insight of the variability?

Lines 188-191. “The most intense PM1 peaks are associated with ship arrivals and departures ...”

Could you provide the quantify the difference in the median and these most intense peaks? How much is this increase in PM1, PN, Org, BC, NO_x relative to sulfate? Relative and absolute differences would be good to list here.

Line 237. “The NO_x EF from ferries show significant variability, ranging from 5.2 g/kg_{fuel} to 72.5 g/kg_{fuel},”

While it is great to provide the range of values, to best capture the variability, the standard deviation should be provided.

Line 254. “though engine design (Tier I for D, Tier II for A, B, C, E)”

Can you explain what the “though engine design” is and what each tier means? This is not explained in the main text nor supplement.

Lines 275-276. “This CO EF, ranging from 0.03 g/kg_{fuel} to 1.90 g/kg_{fuel} (median of 0.28 g/kg_{fuel}), show small variation across ship types or vessel size.”

Remove “This”. “show” should be “shows”, but is the implication of small variation across ship types or vessel size based on the listed range? The upper limit of the range is over 6 times the median and the median is over 9 times the lower limit of the range. This tells me that it is highly variable (though, standard deviation should also always be included when discussing variability), so what would support the argument that there is small variation across ship types or vessel size?

Lines 285-285. “The highest values are observed for ferries A, B and D characterized by powerful auxiliary engines (more than 6,000 kW cumulated for each ferry).”

Is it possible to correlate auxiliary engine power with Org EF?

Line 516-517. “The overall fraction of OA related to transport (road and maritime) is quite high accounting for almost one third of the total OA (29.2 %).”

“Quite high” relative to what? Any reference?

Section 2. Can you define the criteria for a plume? How long are each of the plumes? How well does linear interpolation of EFs represent the background? Can you provide any metrics that capture the uncertainty? Perhaps a figure of a plume event which captures the duration of the plume and the variability of EFs would suffice.

Section 3.2. A literature table in the supplement with all the references cited in the main text for each EF would be helpful.

Section 3.2.1. If more powerful auxiliary engines lead to more SO₂ emissions, can you provide a correlation of engine power to SO₂ EF? How much of an increase in engine power (kW) results in an increase in EF of SO₂?

Section 3.4.2. Could you provide an explanation for the diurnal cycle of the cooking organic aerosol lacking meal time peaks in mass? Could this factor rather just have a continental origin rather than cooking?

Section 3.5. How does the PNSD when selecting the 10 most intense peaks of each factor compare to the PNSD when each factor makes up a certain threshold of the mass? Can you validate this method in finding a representative PNSD in other ways?

Figure 1. The caption lists chloride as a species that is plotted, but according to the legend, it is missing from the figure. Please either include it in the figure or remove from caption and provide reasoning for its absence.

Figures 2 and 4. These figures are not referenced anywhere within the main text, which suggests that either 1. they are not significant enough for the main text and should be in the supplement or 2. more text is needed to incorporate these figures. Since Figure 3 is referenced in Section 3.2.5, I suggest that figures 2 and 4 should be referenced in the other sections in Section 3.

Table S2, S6, S7, S11, S12, S13. These tables are not referenced anywhere within the main text.

Has work been done to see if the increase in shipping emissions is affected by the number of ships? This is especially relevant as your results section discusses the need to address fleet evolution.

Are there other meteorological parameters such as relative humidity and temperature that are available? Is there any consideration as to how these might affect measurements?

Technical Comments

Line 27. Explicitly define UFP as ultrafine particles. PM₁ and PM_{0.1} are listed but are not explicitly defined as particulate matter with a diameter of ≤1 micron and 0.1 microns, respectively.

Line 53-54. “These technologies enable also compliance of environmental regulations for ships running on Heavy Fuel Oil (HFO) with sulfur content exceeding 0.5 % (Laasma et al., 2022).”

Change to “These technologies also allow for the compliance of environmental regulations for ships running on Heavy Fuel Oil (HFO) with sulfur content exceeding 0.5 % (Laasma et al., 2022).”

Line 55-57. “The adoption of low-sulfur fuels in maritime transport significantly reduces exposure to fine and ultrafine particle emissions (Mwase et al., 2020),...”

Change to “The adoption of low-sulfur fuels in maritime transport significantly reduces the emission of and related exposure to fine and ultrafine particles (Mwase et al., 2020),...”

Line 58. “...despite these advancements,, the use of these new”

Remove the second comma.

Line 64. “...transport contribution of 35.2 %and 4.2...”

Add space after the %, before “and”.

Line 96. “15 and 661.2 nanometers”

This is the only example where nm is written out explicitly. To be consistent with the rest of the paper, replace with “15 nm and 661.2 nm” as done in Lines 546 and 557.

Line 98. “ which combines a 3080 Electrostatic Classifiers with a Classifiers with a Differential Mobility Analyzer (DMA 3081), a Condensation Particle Counter (CPC 3775), and a 85Kr neutralizer.”

Change to “ which combines a 3080 Electrostatic Classifier with a Differential Mobility Analyzer (DMA 3081), a Condensation Particle Counter (CPC 3775), and a 85Kr neutralizer.”

Lines 99-100. “CO₂, CO and CH₄ was measured by Picarro analyzer...”

Change to “CO₂, CO and CH₄ were measured by a Picarro analyzer”

Line 109. “m/z ratios”

Change to “mass-to-charge ratios (m/z)”.

Lines 123-124. “The background has been estimated from measurements taken before and after the plume event.”

This is repetitive to lines 119 to 120: “We use linear fit-based EFs that linearly interpolate background concentrations between the levels before and after the plume...”. I suggest removing Lines 123-124.

Line 142. “...is a method increasingly used to calculate correlation when comparing mass spectra”

Add “the” before “correlation”.

Lines 185-186. “including meteorological data (wind speed and direction) HR-ToF-AMS species and black carbon, as well as PN, PM and gases (NO_x and SO₂).”

This is difficult to read. I am not sure what are the criteria for adding commas. I suggest, “including meteorological data (wind speed and direction), aerosol composition (HR-ToF-AMS species and black carbon), as well as PN, PM, and gases (NO_x and SO₂).”

Line 189. “130 to 290° (northwest to east)”

If 290° is considered northwest, then 130° should be considered southeast. Lines 205-206 define “130 to 290°” as southeast to northwest, so be consistent.

Lines 203-205 “When particle number concentration peak exceeds twice the average background level and originates from the sea is attributed to a ship plume.”

Change to “When the peak in particle number concentration exceeds twice the average background level and originates from the sea, the source is attributed to a ship plume.”

Line 217. “below the IMO2020 requirements of 0.5 %, the mean SO₂ EF”

Replace the comma after 0.5% with a semicolon.

Line 245. “consistent with Celik et al. (2020) (20±3 g/kg_{fuel})”

Change to “consistent with a previously reported value of 20±3 g/kg_{fuel} (Celik et al., 2020)”.

Line 247. “...four times higher than the median EF reported in Marseille by (Le Berre et al., 2024) (5.4 g/kg_{fuel})...”

Change to “higher than the median EF of 5.4 g/kg_{fuel} reported in Marseille by Le Berre et al. (2024)”. When directly referring to a study (such as here when using “by”), only the year should be in parenthesis. This was correctly done in Lines 72, 234, and 263, for example.

Line 249. “...as reported by (Bai et al., 2020).”

Change to “as reported by Bai et al. (2020).”

Line 250. “The EF of CO vary from...”

Change “vary” to “varies”.

Lines 256-257. “The median CH₄ EF of 1.0 g/kg_{fuel} is slightly higher than values reported from Marseille in 2021 of median 0.4 g/kg_{fuel} (Le Berre et al., 2024) and similar to reports from Volent et al. (2025) (median of 0.99 g/kg_{fuel}).”

Change to “The median CH₄ EF of 1.0 g/kg_{fuel} is slightly higher than the median value of 0.4 g/kg_{fuel} reported from Marseille in 2021 (Le Berre et al., 2024) but similar to the median value of 0.99 g/kg_{fuel} reported by Volent et al. (2025).”

Lines 257-258. “This EF is considerably higher than other studies with EFs of 0.02 g/kg_{fuel} and 0.05 g/kg_{fuel} from (Cooper, 2003; Timonen et al., 2022), respectively.”

Change to “This EF is considerably higher than other studies with EFs of 0.02 g/kg_{fuel} (Cooper et al., 2003) and 0.05 g/kg_{fuel} (Timonen et al., 2022).”

Lines 259-260. “Among the ships identified none was LNG-fueled, but the yachts exhibited highest CH₄ emissions...”

Change to “Among the identified ships, none were LNG-fueled, but the yachts exhibited the highest CH₄ emissions...”

Lines 261-262. “Inadequately tuned engines, such as those on yachts tend to emit much more methane, in line with the emissions for small vessels as previously reported by Wang et al. (2022) (5.2 g/kg_{fuel}).”

Change to “Inadequately tuned engines, such as those on yachts, tend to emit much more methane, in line with a reported EF of 5.2 g/kg_{fuel} for small vessels (Wang et al., 2022).”

Lines 273-275. “The mean CO EF of 0.38 g/kg_{fuel} is consistent with literature reported in Marseille in 2021 (Le Berre et al., 2024) (0.48 g/kg_{fuel} for maneuvering ships) and with a cargo vessel (0.48 g/kg_{fuel}) (Huang et al., 2018) and reflects typical emissions from diesel marine engines using low-sulfur fuels.”

Change to “The mean CO EF of 0.38 g/kg_{fuel} is consistent with previously reported CO EFs of 0.48 g/kg_{fuel} for maneuvering ships in Marseille in 2021 (Le Berre et al., 2024) and for cargo vessels (Huang et al., 2018), reflecting typical emissions from diesel marine engines using low-sulfur fuels.”

Lines 280-281. “...in quite good agreement with literature values reported by Le Berre et al. (2024) (median 0.86 g/kg_{fuel}), Celik et al. (2020) (mean 3.0 g/kg_{fuel}), and Diesch et al. (2013) (mean 1.8 g/kg_{fuel}).”

Change to “...in quite good agreement to a previously reported median value of 0.86 g/kg_{fuel} (Le Berre et al., 2024) and mean values of 3.0 g/kg_{fuel} (Celik et al., 2020) and 1.8 g/kg_{fuel} (Diesch et al., 2013).”

Line 286 The EF of PAHs, corresponding to the sum of PAHs families defined by Herring et al. (2015), exhibits a mean value of 10.3 mg/kg_{fuel}, aligning closely with values from Celik et al. (2020) (mean 11 mg/kg_{fuel}) and Diesch et al. (2013) (mean 5.3 mg/kg_{fuel}).

Change to “The EF of PAHs, corresponding to the sum of PAHs families defined by Herring et al. (2015), exhibits a mean value of 10.3 mg/kg_{fuel}, aligning closely with reported mean values of 11 mg/kg_{fuel} (Celik et al., 2020) and 5.3 mg/kg_{fuel} (Diesch et al., 2013).”

Lines 292-294. “The mean EF for SO₄²⁻ is 0.13 g/kg_{fuel}, reflecting a significant decreased compared to previous reports, being approximately 30 times lower than the 4 g/kg_{fuel} value reported by (Celik et al., 2020) and 4 times lower than that of Diesch et al. (2013) (0.54 g/kg_{fuel}). This reduction is consistent with more recent findings of Le Berre et al. (2024) (median of 0.05 g/kg_{fuel}).”

Change to “The mean EF for SO₄²⁻ is 0.13 g/kg_{fuel}, approximately 4-30 times lower than the SO₄²⁻ EF values reported by Diesch et al. (2013) and Celik et al. (2020), but consistent with a more recent study that found a median SO₄²⁻ EF of 0.05 g/kg_{fuel} (Le Berre et al., 2024).”

Line 461. Add space before “Conversely”.

Line 588. “...due to their reduced size,”...

Replace “reduced” with “smaller”.