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## Reply on RC2

Helen L. Fitzmaurice and Ronald C. Cohen

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Author comment on "A method for using stationary networks to observe long-term trends of on-road emission factors of primary aerosol from heavy-duty vehicles" by Helen L. Fitzmaurice and Ronald C. Cohen, Atmos. Chem. Phys. Discuss.,  
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### Reviewer 2:

In this manuscript, the authors calculated the on-road emission factors of heavy-duty vehicles (HDV) in the San Francisco Bay area using BAAQMD's ambient monitoring data. The results show that the HDV emission factors decreased by a factor of 7 in the past decades, which is in line with other near-road and tunnel observations in the US. And the authors also found that the HDV emission factors have large spatial variations. The monitoring data from BAAQMD's monitoring network was also used to estimate people's exposure to primary PM<sub>2.5</sub> from HDV emissions in this study. Overall, I think the method developed by the authors is potentially useful and can be applied to other EPA near-road stations to estimate HDV emission factors around the US. However, the emission factors estimated by this method are highly uncertain, and the authors haven't fully characterized the uncertainty associated with this method.

Thank you for these comments. We have used your suggestions below to further characterize the uncertainties associated with our method.

- Since the time resolution of the monitoring data is very low (1-h), it is challenging to separate the HDV emissions from the background, and the choice of background concentrations can significantly affect the results. In this study, the authors used the 10th percentile of all measurements collected within a 5-hour window across the entire San Francisco Bay area as the background, which seems arbitrary.

We include a sensitivity test to the time-window chosen in section S4.

The authors need to run more sensitivity tests about the background concentration. How different would the emission factors be if another percentile was chosen as background?

We added tests of the sensitivity of the derived HDV emission factor to the inferred background concentration, by using the 5<sup>th</sup>, 10<sup>th</sup>, 15<sup>th</sup>, 20<sup>th</sup>, and 25<sup>th</sup> percentile to calculate background concentration. We find that while changing the percentile results in differences to the estimated HDV emission factor that are small in comparison to year over year differences. We have added a section S4 to the supplement, discussing this analysis.

For each near-road station, if you only use concentrations measured at the closest station

or the lowest concentration measured at stations within a closer distance (like 10 km), how different would the calculated HDV emission factor be?

Most stations are greater than 10 km from one another, meaning this method would not be practical to implement for the BAAQMD network. This would be interesting to explore further in the case of denser networks such as Purple air or BEACO<sub>2</sub>N (Shusterman et al., 2016; Shusterman et al., 2018; Kim et al., 2018; Kim et al., 2022).

- For the background-corrected PM<sub>2.5</sub>-to-CO ratio shown in Figure 3, the authors should do the fitting using the original data instead of binning the CO concentration. By binning data, a tiny portion of data in the high delta CO range (>0.8 ppm) is dragging the overall fitting.

As suggested, we now use all the original data not filtered by wind or fire criteria in the fits. We initially used medians of bins to eliminate the impact of noise we thought to be from non-highway sources. However, by implementing a wind filter as suggested above, this noise was reduced, so when combined with the addition of a wind filter, fitting all data instead of binned data has little impact on the derived emission factors. We include a comparison table here. Un-highlighted values are from our original method, using median point values only in fitting. Highlighted numbers are generated through slopes found fitting all data (and wind filtering), as now shown in Fig. 4. (All values are HDV EF estimates in g PM<sub>2.5</sub> / kg fuel.)

With the exception of Redwood City in 2009-2011 and San Rafael 2018-2020, these numbers match to within current error estimations (Fig. 4). In both of these cases, original values were higher, possibly indicating a contribution from nearby non-highway sources. Using all data points instead of bins allows us to estimate an emission factor for Berkeley Marina in 2015-2017 as well, although the estimated uncertainty is large relative to the estimated emission factor. Because this site came online during the 2015-2017 period, by using the binning method, we did not have enough points to fit a line.

<b>TIME PERIOD</b>	<b>SAN RAFAEL</b>	<b>REDWOOD CITY</b>	<b>BERKELEY MARINA</b>	<b>PLEASANTON</b>
<b>2009-2011</b>	0.98	.48	N/A	N/A
	1.10	0.31	N/A	N/A
<b>2012-2014</b>	0.94	0.08	N/A	N/A
	0.86	0.10	N/A	N/A

<b>2015-2017</b>	0.32	0.05	N/A	N/A
	0.42	0.05	0.50	N/A
<b>2018-2020</b>	0.21	0.02	0.17	0.38
	0.11	0.05	0.15	0.36

The authors should also estimate the uncertainty associated with this fitting and propagate it to the overall uncertainty range.

We now show the uncertainty in the fitting in S5. We propagate this uncertainty, as described in Sect. S6, and use this uncertainty propagation to add error bars to Figure 4.

- The authors need to thoroughly discuss uncertainties associated with all terms in Equation 1 and 2 and propagate them to the results.

We add a discussion of the uncertainties associated within each term, as well as the propagation of these uncertainties to the supplement. (See Section S6.) We use the described uncertainty propagation to characterize uncertainty in the emission factors we show in Figure 4.

- The emission factors in Figure 4 should have uncertainty bars. Because the method has large uncertainties from the choice of background concentrations, the spatial variation estimated using this method may not be real. How were the traffic speed and slope of the road at those near-road stations? The spatial variation may also be caused by traffic speed and road slope.

We add uncertainty bars to the emission factors in Figure 4 as discussed in response to previous comment. We agree that on-road factors such as traffic speed and road slope may have a substantial impact on emission factors. None of the lengths of roadway in Figure 4 are subject to a substantial grade. We incorporate day-to-day variance in traffic speed into our new uncertainty calculation.

- Did the authors try analyzing the monitoring data around noontime? The HDV traffic is usually the highest around noontime.

We do not try analyzing the data at noontime, because by that time the boundary layer height is substantially larger than during the AM rush hour, meaning that emissions are likely to be substantially more dilute before reaching BAAQMD monitoring sites than in the AM. While HDV emissions may be slightly higher at noontime than during AM rush hour, they are not substantially so (< 25% higher for all sites examined).

- The wind speed and wind direction data are also measured at BAAQMD's monitoring stations. Why did the authors use wind data from the reanalysis product instead of the

measurements at monitoring stations?

We use the ECMWF reanalysis product instead of the measurements at BAAQMD monitoring stations, because the meteorological measurements at the BAAQMD monitoring stations are unreasonably difficult to access. While BAAQMD posts meteorological data to its website, to the best of our knowledge, there is no API for BAAQMD meteorological measurements that we could find. For example, while BAAQMD air quality measurements can be downloaded using the EPA's API service, wind speed and wind direction are not available via this service.

- The authors should be more careful about using parameters derived from the EMFAC model to calculate on-road HDV emissions. The emission factors estimated by the authors are under the situation when HDVs are driving on-road at a certain speed with a particular road slope. However, the emission factors modeled by EMFAC consider the entire driving cycle, different seasons, different types of fuels, and all driving conditions. The authors should provide more details about how they ran the EMFAC model.

This is a good point, as both fuel efficiency and emission factors from other pollutants can vary considerably as a function of specific driving conditions. We have created a new methods section (2.4) in which we detail how we run the EMFAC model to estimate CO emission factors as well as emission rates (g CO<sub>2</sub> / vkm). The methods we use follow those in Fitzmaurice et al., 2022. We also add the impact of speed variance on emission factors to our estimation of uncertainty in HDV PM emission factors.

Please also note the supplement to this comment:

<https://acp.copernicus.org/preprints/acp-2021-1042/acp-2021-1042-AC2-supplement.pdf>