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Atmospheric Measurement Techniques Discussions

Interactive comment on "Mobile-Platform Measurement of Air Pollutant Concentrations in California: Performance Assessment, Statistical Methods for Evaluating Spatial Variations, and Spatial Representativeness" *by* Paul A. Solomon et al.

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Responses to Anonymous Referee #1

Thank-you for your helpful questions and suggestions. We summarize our responses here following each question. We will add these responses at appropriate places in the revised manuscript or in the supplement.

1. Some information on the cars should be included, not just referenced in another paper. Were the cars' engines running while parked (e.g., in the garage, near stationary monitors, etc.)? What was used to power the instruments?

The instruments were switched from vehicle to line power in the parking garage or parking lot.

2. It is great that the inlets were designed to minimize self-sampling, but were additional steps taken during post-processing to remove potential periods of self sampling, or of sampling the Google car in front?

The cars generally followed different routes, such as those illustrated in Figure 7 or in Figures S3, S6 – S8, and S10 – S15. Therefore, sampling the exhaust of a partner car was seldom an issue. When the cars traveled a route segment together (e.g., Figure S15), they could not travel side-by-side because that would block the flow of traffic. The drivers instead traveled "caravan style", keeping each other in sight but not following immediately one behind the other.

3. It would be good to document the limitations of the study (e.g., no overnight monitoring on roads or in early morning when the boundary layer is likely at its lowest).

Please see the new paragraph that we posted as a general response.

4. Table 1 - was winter included in the San Joaquin Valley measurements (Nov '16-Apr '17) or was it just fall and spring?

Sampling was conducted in the San Joaquin Valley between November 2016 and April 2017. We did not attempt to analyze the full set of measurements because another manuscript will likely be needed to fully describe the intracity, intercity, and urban-rural differences encountered in this geographically large domain. No single area was

sampled throughout the entire period.

5. Section 2.2 - were the cars parked on the roof of the parking structures or on a lower level? Depending, this could explain why GPS uncertainties were not comparable to manufacturer specs at times. Tall buildings nearby (if present) would also impact GPS performance.

In San Francisco, the cars were parked within a parking structure. In Los Angeles, the cars were parked in a small ($\sim$10 car) open parking lot. We will correct this statement (e.g., at lines 109, 113, 165) in the revision. We do not have an explanation for the observed variations in the GPS location uncertainties, but report them for completeness.

6. Lines 286-289: the closely-spaced moving vehicle condition makes it highly likely that the following car is measuring exhaust emissions from the lead car. This point should be mentioned in the manuscript. Did you try to correct for this? Why not drive side-by-side (road permitting)?

Please see our response to #2.

7. Could you please provide a list or table in the SI with the manufacturer and model of all instruments used in the study along with response time and measurement frequency. Even if this information was referenced in another paper, it should be reported here.

We will add this information to the supplement. The instrumental methods, resolution, ranges, and response times are listed in the Lunden and LaFranchi (2017) citation and can be added to the supplement.

8. Did you sync all instruments to the same time standard before measurements? Did you check instrument times at the completion of each day's measurement to quantify time drift? At measurement frequency of 1Hz, time drift can have a major impact on data comparison. These details should be included in the methods section.

We will clarify this point at line 137. The on-board computers are synchronized through-

out the day using network time protocol, which synchronizes computers to Coordinated Universal Time (UTC) with accuracies on the order of milliseconds. This approach was necessary to ensure that the 1 Hz measurements did not drift.

9. By comparing 1-min averages, which I understand is important in order to maintain higher spatial resolution, how are you able to separate out the spatial trends due to differences in regional concentrations as opposed to differences in measurements due to some very localized conditions (e.g., driving behind a truck for a short period of time with one Google car but not the other over the same time period)? Would some other comparisons be more appropriate, such as a 60-second moving 5th percentile, or something comparable, to smooth out hyper-local concentrations?

Several different comparisons were made at 1-minute or coarser resolution. For the Los Angeles car-to-car comparisons, we examined both bin-average FAMD and variability within bin averages. Random differences between vehicles, such as short, intermittent exposures of one car or the other car to a high emitter, are averaged out in the FAMD statistic. In contrast, systematic car-to-car differences yield higher FAMD values. We identified some specific geographical patterns associated with higher FAMD (lines 352 – 355). As noted, the approach developed for studying the San Francisco data could also be applied to the Los Angeles data for a more comprehensive analysis.

For the San Francisco data, we aggregated 1-minute differences to a 1-km spatial scale (lines 402 – 410). Large mean differences were plotted in Figure 6 only if they were statistically different from zero (i.e., the interval of the mean difference $\pm$ 2 standard errors of the mean did not cover zero) so that atypical car-to-car comparisons did not artificially create apparent spatial patterns. The rationale is that the standard errors of the 1-km averages would be large if one or more paired differences was very large; this would indicate the occurrence of an unusual condition.

10. I am struggling to understand why plotting the measurements against distance between either the cars or between car and stationary monitor is the best way to present

the data. Had the cars been driving different routes than the ones presented, the plots would be completely different? The distance between the cars is not driving the differences observed, it is the difference in the environments of the two cars at any given time. For example, the cars could both be in heavy traffic at 50 km away from each other (thus mean differences in concentrations are low), then at 75 km distance one car is still in heavy traffic while the other is in a quiet neighborhood away from highways (thus mean differences in concentrations are high). For example, Figures S16 and S17 are interesting, but it would be more informative to provide information on where each of the cars are (e.g., land use, traffic conditions, major roadway, etc.) when FAMD is higher or lower irregardless of the distance between the cars. Are all points where the cars are X distance away from each other aggregated together even if the positions were discontinuous? If so, I do not know how one could interpret this plot.

This issue clearly affects the data from the San Joaquin Valley, where the cars were separated by larger distances than in Los Angeles or San Francisco. As noted by the reviewer and as shown in Figures S15 and S16, for some species, differences in environments can drive car-to-car differences when the vehicles are separated by more than a few kilometers. In contrast, Figure S17 shows the expected regional character of ozone with FAMD values < 0.2 at all intervehicle distances < 50 km. We conclude that smaller FAMD values indicate greater spatial homogeneity; larger FAMD values require further study beyond the plots of FAMD vs. distance. As one example, Tables S1 – S4 summarize car-to-car comparisons that are stratified by sampled areas. We expect that more complete analyses of the San Joaquin Valley data will be quite informative but will require another manuscript to fully explore.

11. Section 3.6 (lines 476-479): An FAMD of 0.5 seems high to conclude that a reference monitor is representative of a neighborhood scale area.

We will revise this statement to note that the majority of the NO2 FAMD values were less than 0.2 at car-monitor distances of 0.5 – 4 km. We noted the higher FAMD for NO.

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