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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Quantifying population exposure to airborne particulate matter during extreme events in California due to climate change" *by* A. Mahmud et al.

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Introduction: Only one other study is discussed in the context of investigating the impact of climate change on particulate concentrations. There are many others – Dawson 2007, Kleeman 2007, Pye 2009, to name a few. Thorough discussion of the literature should be presented.

Response: The objective of the current study is focused on the climate change effects on human health through PM exposure. The references of Pye et al. (2009) and Dawson et al. (2007), which evaluate the climate change impact on chemical composition in PM will be cited as suggested. Current and previous articles on climate change im-

pact on human health due to PM exposure will also be cited in the introduction section of the update manuscript.

5885.22: Why are mobile source emissions impacted by variations in meteorological conditions? Overall, it's not clear to what extent changes in meteorology are being decoupled from changes in emissions. I would have thought, from the introduction, that only changes to biogenic, soil or lightning emissions (i.e., natural processes) would be affected by climate alone, and that all of the anthropogenic emissions would be fixed. This would be consistent with the attempt to minimize "confounding factors," such as changes to population. This could use clarification.

Response: The basecase emissions activity is held constant in the current study, but those basecase emissions still respond to meteorological conditions. Biogenic emissions and evaporative emissions from motor vehicles both increase as temperature increases even though the underlying distribution of vegetation and motor vehicles has not changed.

5886: To what extent does the model reproduce observed variability in 3 year average PM2:5 concentrations by species? Some assessment of the forward model performance relative to observations needs to be included, either directly or via discussion of previous work.

Response: A discussion of the climate-air quality model performance from Mahmud et al. (2010) will be added to the revised manuscript. Predicted annual average total and speciated mass concentrations of fine particulate matter (PM2.5) were compared with measured concentrations at six representative sites in heavily populated air basins in California for the present-day (2000-06) period. The air quality model under-estimated annual average PM2.5 mass concentrations by $\sim$4-39% due to over-predictions in downscaled wind speed. Measured annual average PM2.5 total mass concentrations were $\sim$20$\pm$2 μg m-3 in the SoCAB and SJV compared to predicted concentrations of $\sim$13-18 μg m-3. The model also under-predicted components of PM

mass such as elemental carbon, organic carbon, nitrate and sulfate due to these same wind speed over predictions. The bias in downscaled windspeed is assumed to be constant between present and future climate periods. The relative standard deviations (standard deviation divided by the mean) of PM2.5 mass predictions are 2%,3%, 6% and 9% for the present (2000–2006), and 5%, 6%, 8% and 7% for the future (2047–2053) periods at Riverside, central Los Angeles, Bakersfield, and Fresno, respectively. The value of 9% relative standard deviation for Fresno in current climate compares favorably to the measured value of 10.5% relative standard deviation for the San Joaquin Valley between the years 2000-07 (statistics calculated from monitoring data available at arb.ca.gov).

5889.7: I'm not sure that "statistically identical to zero" is entirely correct here. It is possible for two statistics to have overlapping CI's but be statistically different at a particular level of significance. Was the mean determined to be statistically different than zero? At what level of significance?

Response: We simply stated that the changes are not statistically significant in the update version of the manuscript to avoid the mis-understanding.

If the largest differences seen between the present and future climate cases were in the extreme events, did the authors consider the relevance of their work with regards to acute health effects? This would seem to me like a natural impact to explore, or at least mention.

Response: The majority of the health effects acknowledged by the epidemiological community are associated with mortality linked to long-term averages of PM2.5 concentrations. A robust statistical treatment of health effects associated with short term exposure to extreme PM2.5 concentrations is not present in the literature at the present time. We would welcome a reference from the Reviewer to any techniques that can quantify health effects of exposure to PM2.5 during extreme events.

The investigation of differences in the upper 1% of the distributions is bothersome for

a few reasons. First, the plot referred to by the text doesn't even show the part of the histograms being compared here. Also, this plot S3 would appear to be central to a large portion of the results. The manuscript is very short at present – I suggest including this figure in the main text. Lastly, it's not clear to me to what extent a single percentile between two distributions with this much variability can be explained. What statistical test can be done to determine if the difference between these extreme values are statistically significant? Is it arbitrary to focus only on the 99th percentile, i.e., couldn't the authors similarly have compared the differences between the histograms at the bin around 11μg/m3?

Response: The 99th percentile events correspond to the 10 days with the highest population-weighted PM2.5 concentrations in present and future climate. We analyze these extreme events using extreme value analysis (EVA) and we could have chosen to plot 10-year return levels for PM2.5 concentrations. We felt that presenting the actual sample information (ie – the 10 highest days) was more concrete (less abstract) than presenting the EVA model fit to those extreme values. An inset has been added to Figure S3 to more clearly illustrate the behavior of the tails of the distributions.

Throughout, the authors invoke the notion of increased stagnation as governing the differences in the present vs future climate. Was that really the only difference? Did changes in temperature, precipitation or deposition really have no impact? If not, why were these factors noticed in other studies in the literature but not this manuscript?
Response: Averaging over 7-year analysis periods, changes in precipitation and temperature produced effects that were not statistically significant in the context of natural inter-annual variability. This may be a consequence of the dominant meteorological patterns in California, or the previous studies finding these factors to be important may not have analyzed sufficient time periods to fully evaluate the statistical significance of those results. Conditions during extreme events in California are similar with no precipitation and stagnant high pressure conditions dominating temperature and wind speed. The degree of wind stagnation therefore becomes the dominant factor during

these extreme events.

5891.21: This is probably related to me not understanding clearly which emissions are fixed, and which emissions are affected by climate change, but why is there such a large decrease in SO42- here?

Response: As discussed in response to a comment from Reviewer 2, the 10-year return levels for PM2.5 EC (+23%) and NO3- (+58%) averaged over the statewide population were predicted to increase in the future while statewide 10-year return levels for PM2.5 SO42- (-46%) were predicted to decrease. These trends reflect increased stagnation during future pollution events which traps pollutants close to their emissions source and provides greater time for the formation of secondary products. NOx is emitted in close proximity to population centers by combustion sources such as motor vehicles, leading to increased population exposure to NOx reaction products such as NO3- when stagnation increases. SOx is emitted from industrial facilities and from goods movement sources such as ships, leading to decreased population exposure to SOx reaction productions such as SO42- when stagnation increases.

Minor Comments

5882.14: This paragraph of the abstract seems to be missing on overall topic sentence, and thus the reader assumes the first sentence to be an overview, but really the following discussion focuses not on the lack of changes in the mean mass concentrations but rather the estimates of significant changes to the composition.

Response: The first sentence in the second paragraph in abstract will be revised to read “The current study found that the change in annual-average population-weighted PM2.5 mass concentrations due to climate change between 2000 vs. 2050 within any major sub-region in California was not statistically significant.”

5883: “2.3” seems like a rather precise factor to be conjoined with the approximation symbol $\sim$.

Response: We believe the climate down-scaled air quality model output is an estimate, hence the approximation is used to describe the predicted concentrations and/or any changes based on the model output.

5883.21: remove “trapping” Response: This will be fixed in the updated manuscript.

5886.27: What are the units of Ci? Are the volumes of each of the grid boxes the same, i.e., the height of the first model layer is fixed? If not, summing up concentrations in this manner would not be appropriate.

Response: Yes, The height of the first layer of the model is set be 37 meter above ground and it is fixed. So the volume of each grid cell is fixed for the surface layer.

5886.12: The modifications mentioned here to wet deposition schemes and sea salt emissions need to be explained further (or were these part of the Mahmud 2010 updates? It wasn’t clear).

Response: Yes, the detailed of the modifications of wet removal processes and sea salt emissions has been given by Mahmud et al. (2010)

5887: A figure showing this distribution would be helpful.

Response: The GPD fit to the extreme values will be shown in Figure S3 of the revised manuscript.

5888: It’s not clear to me why the y-axis on Fig 2 is set to 50 given that the scale of the results is much narrower.

Response: This has been done in order to keep y-axis of Fig. 2 consistent with Fig. S1 in the supplemental where the changes go up to >40% for nitrate and ammonia. This will be modified in the updated version of the manuscript.

5890.3: Have GCM and RCM been defined?

Response: Global Climate Model (GCM) and Regional Climate Model (RCM) will be

defined in the introduction of the revised manuscript.

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