

Comment on “Multiscale atmospheric modeling suggests ammonia is necessary but not sufficient to explain new particle formation in the Colorado boundary layer”

The manuscript titled “Multiscale atmospheric modeling suggests ammonia is necessary but not sufficient to explain new particle formation in the Colorado boundary layer”, the authors simulated NPF in Colorado using a global model nested down to 3 km resolution and compared their results against the field and aircraft campaign measurements from FRAPPE and DISCOVER-AQ. The authors used 2 NPF parameterizations the ion-mediated SA-NH₃ from Dunne 2016 and the binary SA-H₂O from Vehkämäki 2002. They also attempted to qualitatively address the errors that either led to under-or-over estimation of the results. The article is well-written, although it could benefit from streamlining certain sections and thoughts. The results are presented succinctly but lacks discussion in a few sections. I would recommend the article for publication, if the authors are able to address the following queries.

General comments:

1. Lack of statistical comparisons. This is a model-measurement comparison article but it lacks an statistical comparison between the modelled and measured values of e.g gas-phase precursors and particle concentrations in different size modes.
2. The introduction although tries to encapsulate the basis for the work but is not streamlined. It could benefit from rethinking the order in which different concepts are introduced (See an example in specific comments).
3. From a curiosity point of view, have the authors considered applying NPF look up tables such as J-Gain (<https://egusphere.copernicus.org/preprints/2023/egusphere-2022-1464/>) in their model? Earlier simulation that implemented this look up table in EC-EARTH (<https://gmd.copernicus.org/articles/17/4923/2024/>) did show that an improvement in aerosol concentrations when compared to measurements. I also wonder why ELVOC-SA parameterizations from Riccobono was not implemented for this work, where even the authors claim that organics might play an important role in NPF at these sites?

Specific comments:

Abstract L 13-14: aerosol number concentrations in which size? sub nm, Aitken, accumulation or coarse mode?

L29-35: Some examples of “other compounds” and regions can be introduced here. e.g. IA, MSA in marine and polar regions to strengthen the idea that compounds without SA can nucleate.

L42-44: I think that the introduction could be streamlined. First the authors can introduce the nucleating precursors and then move on the detail the parametrizations used in CMIP6 and CTMS. lines 29-31 can be clubbed in the paragraph starting on line 42.

Table 1: How do the emissions from CMIP6 and EDGAR 2014 compare against each other?

L111-112: Aren't there 7 size distribution log-normal modes in GLOMAP?

L141: I would suggest adding examples for these rather than just stating it.

L156-160: what was the mean ion production rate for the study period over the study region?

L168, eq 3: This ternary parametrization is different from the one defined in D2016 supplement section 8. This is from Gordon 2017. I would suggest the authors to mention that this the eq1-3 are from Gordon 2017.

L193: "We applied this correction factor here, as it is most likely better than not doing so". Shouldn't the reason be that since you are studying vertically resolved observations, taking RH into account will impact formation rates at cloud bases and in low level clouds?

Tabel 2: Is the bao tower surrounded by forest or is it close to urban region?

L292-296: I am assuming that the QC would have flagged this exhaust measured events?

L303-304: Please provide the factor or overestimation of SA.

Figure 2: "aggregated"? what does aggregated mean? is it cumulative?

L330: I would suggest adding the 27th event in the main manuscript and not in supplement, since these are the main 2 events being discussed here.

L331-332: this is a contradictory statement. Aikten mode aerosols, formed via NPF, which don't grow into Aitken mode? such a high number of particles are more representative of NPF.

Figure 5: for clarity add the BAO and DENVER to all subplots.

Figure 5: can you explain the npf event in the grid 40-41N and 104-102 W?

L339: "Centered". what does this mean?

L340-341: can you add these as boundary markers in Figure 5? helpful to the readers to understand.

L361-363: this doesn't seem right. D2016 has larger total particle conc. estimates than V2002.

L363-365: does this hold up when V2002 appears to have lower total particle conc. than D2016?

L365-368: "The nucleation-mode aerosol number concentration is simulated

realistically on 31 July but substantially overpredicted on 27 July by the D2016 scheme, while essentially no nucleation-mode aerosols are formed at the altitude of the aircraft in the simulation with the V2002 scheme". which figure shows this?

L379-381: "The overestimate is co-located in the size spectrum with the primary 'Aitken insoluble' mode so may result either from the NPF or from overestimated primary emissions. ". can this be confirmed by a sensitivity test by modifying the primary emissions?

L408: "relatively well". what does relatively well mean? I would suggest to run some stats such as mean bias or factor of 2 to show the over or underestimation compared to the measurements.

Figure 10: shouldn't this be termed "number balance" for a more accurate description? mass balance closure would make more sense if there were more observations of organics or other precursors.

L479-484: Could you add the M/O for $n > 100\text{nm}$ and M/O FOR $n < 100\text{nm}$ separately. if M/O $n > 100\text{nm}$ is larger than M/O for $n < 100\text{nm}$ then this argument holds.

Figure 11. are panels c,d D2016-v2002? its be good to include it in the figure caption or title

Figure 12: I would suggest to move this figure to the supplement since it's not being discussed in detail.

L530: What does qualitatively unchanged mean here? are there any stats to back this claim?

L563"" good simulation of sulphur dioxide". I would write it as "agreement in modelled and measured SA" and provide the stats here.