A Review of

A revised version of “Development of the CMA-GFS-AERO 4D-Var assimilation system v1.0- Part 1: System description and preliminary experimental results”

submitted to Geoscientific Model Development by Liu et al. (2024)

Review Decision: Minor Revisions

Manuscript type: *Development and technical papers*

General Comments:

The revised manuscript is a huge improvement from the original version in various aspects, including readability, clarity, and coherence. The authors’ effort on revising the manuscript is greatly applauded. I’ve also found the revised manuscript to be very educational in guiding the readers on developing a coupled aerosol-meteorology 4D-Var assimilation system step by step with important details. After a thorough review, I only have a few minor comments that I’d recommend the authors to address before the manuscript could be considered for publication.

Minor comments:

1. What is a batch test? My guess is that it is an integrated set of tests that involves many cases, but I am not 100% sure since it sounds more like a test used in software development. Is batch test a common terminology used in operational NWP centers? I wondered whether it is okay to assume that the readers understand what a batch test is. I would rather use more words in plain language to describe what the author intends to do next instead of a terminology that might not be universally recognized.

2. Page 1, Line 13: chemical should be replaced by aerosol.

3. Pages 2-3, Lines 36-66: this paragraph is too long. Please consider breaking it into two paragraphs. I recommend that a new paragraph could be started from line 58, focusing on the role of background error covariance in high-dimensional CCMM system.

4. Page 4, Line 103: chemical should be replaced by aerosol.

5. Page 4, Lines 104-105: it should be five sections, not four, as the remaining sections are sections 2, 3, 4, 5, and 6 (total of 5).

6. Pages 4-5, Lines 123-125: aren't those water matter species produced by the double-moment cloud microphysics scheme also considered state variables of the CMA-GFS NLM?

7. Page 8, Line 236: Upon reading this, I couldn't help but wondering that isn't AERO-BC also 1-D modules? And then, I found the authors actually hinted this at page 7 line 198. I suggest making this point clearer upfront. Also, I am puzzled by the description about "1-D modules with fixed latitude and longitude coordinates"… if it has lat/lon coordinates, then isn't it 2-D?

8. Page 13, Line 362: "at the initial of the assimilation window," it would be better to put "only" right after assimilation window to highlight this very special scenario.

9. Page 22, Line 575 and Table 3: I think there is a need to explicitly explain how the two experiments DA_MET_then_BC and DA_MET_BC_simult are conducted differently in terms of their workflows. For DA_MET_then_BC, does that mean the CMA-GFS-AERO 4DVar system is run two times with the same setup, except for the observations being assimilated? In the first run, only the operational meteorological observations are assimilated and then the resulting analysis is used as background for the second run, where only the BC surface observations are assimilated. Is that right?

10. Page 23, Line 602: I am not sure what is the purpose of this sentence.

11. Page 24, Lines 626-627: ok, but why not just show the analysis increment of DA_MET_then_BC and have it compared with those from DA_BC? I still have trouble understanding using the "difference of analysis increment of two experiment" to compare with the "analysis increment of one experiment". If the concern is because the analysis increments of DA_MET_then_BC and DA_BC includes not only the impact of meteorological observations but also the impact from using different background fields (the nature of DA_MET_then_BC), and the authors would like to isolate the impact of BC from all other factors, then it has to be stated clearly to justify such comparison (which also echoes my minor comment 9). However, I am not sure whether the same reasoning applies to the case for comparing the difference of analysis increment of DA_MET_BC_simult and DA_MET with the analysis increment of DA_BC.