

Comments to the Authors

General comments

The study by Schnell et al. demonstrates the potential of RAP-Chem model, that possess tightly coupled physics and chemistry, in improving the air quality forecasts during 2020 North American wildfires. The authors make several modifications to the model and conduct experiments to analyse the impact of processes like aerosol direct effect, updated vertical mixing treatment and effect of subgrid clouds coupled to photolysis scheme. The results mostly deal with impacts on PM_{2.5}, AOD, CO and ozone. The study is difficult to follow up at times but I hope this can be improved with a substantial effort. Hence I strongly suggest that the following comments are addressed before consideration of the manuscript for publication.

Major comments

- (1) Besides ground based observations, it would be good to have comparison with satellite data (like for AOD).
- (2) Line 43-44: I couldn't understand this line, especially the part "NMB improves more significantly". Has there been any significance test conducted?
- (3) Line 148: It is not clear which reaction rates were updated? Any references for modified reaction rates?
- (4) Line 268: On what basis do the authors say that model performs "very well" for meteorological parameters? Are there any relevant benchmarks or references to make such a conclusion about model performance for each of these variables?
- (5) Line 300-301: Similarly, how do the authors conclude that the reported NMB and RMSE values can be considered minimal?
- (6) Line 306: The model output should have NO_x concentrations. Why have the authors not analyzed/evaluated it? It may be good to correlate to ozone discussion along with CO.
- (7) Line 316: Can more details be provided on the transformation. How do the emissions look like without and with transformation?
- (8) Section 3.3: This section is poorly written. Rather than discussing region-wise, I suggest discussing PM_{2.5} first for all regions followed by O₃. Otherwise it becomes slightly annoying to juggle between the two figures (S4 and S5) with (and sometimes within) each paragraph. For e.g.- For EPA region R8, discussion starts with PM_{2.5}, shifts to O₃ and then again shifts back to PM_{2.5} and ends with O₃.
- (9) Line 337-338: How do you infer that PM_{2.5} is better simulated by control for region R8? From Fig. S4, both simulations show very similar behaviors in August.
- (10) Line 340: Again, how is it concluded that prediction is excellent? Are there any benchmarks to suggest that this can be regarded as excellent?
- (11) Line 342: Please put figure number which you are referring to for nighttime low?
- (12) Line 344: **relatively good agreement** – relative to what?

- (13) Line 351: Again, how is it decided that ozone is simulated “extremely well”? Any benchmarks?
- (14) Line 351: How is the ozone decrease from 9-14 September captured accurately? I see bias of more than 20 ppb between observed values and control run.
- (15) Line 366: “**correlation is significantly reduced**” - Is there any significance test conducted to demonstrate the same?
- (16) Line 384: I couldn’t understand this part - during the daytime **due to the condition for low PBL heights**.
- (17) Line 392-393: I could see lower CO over urban areas in Fig. 2e. However, I couldn’t notice increases anywhere in domain. Are the increases very small?
- (18) Line 407: On some days it seems model overestimated as compared to AIRS rather than underestimating.
- (19) Line 409: Elevated where exactly? I couldn’t see elevated levels in *newmix* that drastically differs from other two simulations in final days.
- (20) Figure 3/4: What is the purpose of Fig. 3e/4e related to water vapor? I couldn’t find any discussion on it.
- (21) Line 418: Why does the text directly jump to Fig. 5 without even explaining what Fig. 4 is about?
- (22) Line 453: I could see mostly increase in O₃ rather than reduction in eastern regions in Fig. 5c.
- (23) Line 457-458: I could see *oldmix* also overpredicting at times on August 5.
- (24) Line 471: How is it that *control* accurately predicts the enhancement? There is huge bias still. Even *no_dirfdb* shows enhancement, though with a lag.
- (25) Line 476: It is difficult to see the differences for T_{2m}. Some statistics would be good.

Minor comments

- (1) Line 113: Put 1 more bracket at the end of reference.
- (2) Line 122: 72s is not a ‘reduced time step’ as compared to 60s.
- (3) Line 150: using a modified ~~parameterizations~~ parameterization
- (4) Line 154-155: Line is unclear. Especially the part – “42 species, three of which are the number concentrations”
- (5) Line 168: Line is unclear. Especially the part- “and so use another fuel use based emission inventory”
- (6) Line 198: Equations S1–S3 can come first before the figures in supplement. It is a bit hard to find them at the end. Or they may be put within main manuscript as their description is also included in the following lines.
- (7) Line 200: Put a punctuation mark before sentence starting with “Finally”.

(8) Line 206: wetscav_onoff = -1 or 1?

(9) Line 272-273: Line is unclear. “while biased high ($\sim 1\text{--}3^\circ\text{C}$) over the western regions heavily impacted by smoke, **initially indicating a low bias in simulated aerosols and/or their radiative extinction.**”

(10) Line 305: Do you mean to refer to Fig. S5 for ozone instead of Fig S4?

(11) Line 307: Which minima is being referred to here? What date?

(12) Line 419-420: This line is confusing and long. Kindly rephrase or break into two sentences - Clouds extend from ~ 1 km/900 mb through ~ 5 km/600 mb throughout the region **and below the clouds** (not shown), and newmix CO concentrations....

(13) Line 428: the PBL, and ~~decreases~~ decreased CO (10-20 ppb)

(14) Line 449-450: Lines mention that the cloud cover shown in figure is from *phtmix*. However, title of the Fig. 5a mentions that it is from *newmix*.

(15) Line 472: Its ***no_dirfdb***

(16) Line 515-516: This line is bit weird to read - Surface $\text{PM}_{2.5}$ is generally underestimated in wildfire source regions **as well as the extinction of those aerosols**