We appreciate the time and thoughtful feedback provided by Anonymous Referee #1. The reviewer's comments are shown below in black, with our detailed responses in blue.

After careful revisions by the authors, this paper has been significantly improved. Although necessary information has been provided in the current manuscript, the overall organization of the Results section and the presentation of the scientific storyline could still be improved. The study appears to aim at establishing the following logical chain: Hydrocarbons → Carbonyls → HOx/RO2 → O3 pollution

To clearly support this storyline, it would be helpful to more explicitly explain:

• the general characteristics of O_3 pollution in the study region.

- Three sentences were added at the beginning of Section 3.1 to characterize the O_3 episode before presenting model results. The study period was described in terms of the persistent thermal inversion, continuous snow cover, and progressive O_3 accumulation, with the observed maximum hourly and 8-hour average O_3 values placed in the context of the EPA standard and the broader conditions driving wintertime O_3 in the Uinta Basin.

• the influence of carbonyls on O_3 formation through their contribution to HOx/RO_2 chemistry.

- A bridging sentence was added at the beginning of Section 3.2 to explicitly connect carbonyl compounds to O_3 production through their photolysis and oxidation reactions, which generate HO_2 and RO_2 radicals that drive NO-to-NO_2 conversion and ultimately O_3 formation.

• the influence of hydrocarbons on carbonyl formation and the related chemistry.

- A bridging sentence was added at the beginning of Section 3.3 to explicitly connect the carbonyl findings of Section 3.2 to primarily emitted hydrocarbon groups, framing the section as tracing the origins of the dominant carbonyl O_3 precursors to their hydrocarbon sources.

• the overall contributions of hydrocarbons to O_3 pollution and the implications for pollution mitigation.

- A bridging sentence was added at the beginning of Section 3.4 to frame the sensitivity analysis as completing the logical chain from primarily emitted hydrocarbons through carbonyl formation to O_3 production. The opening of the Conclusion's mitigation paragraph was also revised to explicitly state that the

pathway from primarily emitted hydrocarbons to wintertime O_3 proceeds through secondary carbonyl formation, particularly formaldehyde and acetaldehyde, before identifying alkanes and aromatics as the primary emission reduction targets.

The authors include O3, HOx, and carbonyl budgets in different sections of the Results, but the connections between these analyses and the goals of each section could be further strengthened. For example, in Sect. 3.2, the contributions of carbonyls to O_3 production in different mechanisms are first discussed, followed by an analysis of HOx budgets without clearly stating the purpose of this analysis, and then the roles of different carbonyl species are presented. This way of organizing the information makes it difficult for readers to follow the detailed interpretation of the analyses.

- The connections between the analyses in Section 3.2 have been strengthened. A purpose statement has been added before the HOx budget analysis (Figure 3) to clarify that it is presented to explain the mechanistic basis for the differences in carbonyl-driven O_3 sensitivity observed across mechanisms in Figure 2. This makes the three-part structure of Section 3.2 explicit: Figure 2 identifies differences in carbonyl contributions to O_3 across mechanisms, Figure 3 explains the mechanistic basis for those differences through the HOx budget, and the subsequent discussion of individual carbonyl species identifies which compounds are most important and why. The bridging additions made in response to the previous comment further strengthen the connections between Sections 3.1, 3.2, 3.3, and 3.4.

In addition, the authors are encouraged to compare their budget analyses with those reported in previous studies. My specific concerns include:

1) In the O3 budgets, it is not unexpected that O + O2 is identified as the major source of O3, since it represents the final step of nearly all O3 formation reactions. In many studies, the key source reactions considered in O3 chemical budgets include HO_2 + NO and RO_2 + NO, which directly control the conversion of NO to NO_2. And it would be helpful to discuss why similar O3 budgets lead to different simulated O3 levels in different mechanisms.

- We agree that reporting $O + O_2 \rightarrow O_3$ as the dominant O_3 production pathway, while technically accurate as it represents the final step of all O_3 formation reactions in F0AM, does not provide the most mechanistically informative view of O_3 formation. As the reviewer notes, many studies frame the O_3 production budget in terms of HO_2 + NO and RO_2 + NO reactions, which directly control NO to NO_2 conversion. We have added a clarifying statement in Section 3.1 acknowledging this and directing

readers to the HOx budgets in Figure 3 and Tables S9, where these proximate drivers of O_3 production are explicitly quantified.

- Regarding why broadly similar O_3 budgets lead to different simulated O_3 levels, we have expanded the discussion in Section 3.1 to make this connection more explicit. The key factor is the absolute rate of radical production, which differs substantially across mechanisms despite similar percentage-based O_3 budget structures. In particular, CB6 produces nearly twice as many HOx radicals (38.7 molecules cm^{-3}) as MCMv331, SAPRC07, and RACM2 (21.2, 23.7, and 22.1 molecules cm^{-3}, respectively), driving faster HO_2 + NO and RO_2 + NO cycling and ultimately higher O_3 mixing ratios.

2) The HOx budgets indicate that the major HOx source is HO_2NO_2 decomposition, which is somewhat unexpected based on my experience. It would be helpful if this finding could be supported by previous studies in the same region or in similar environments. In addition, HONO photolysis is often considered an important HOx source; it would be useful to clarify whether it is included in the "other" category. Furthermore, why does PAN decomposition contribute significantly to HOx production in the CB6 mechanism, while its contribution appears negligible in the other mechanisms?

- The dominance of HO_2NO_2 thermal decomposition (23–38% across MCMv331, SAPRC07, and RACM2) is physically consistent with the cold, high-NOx wintertime conditions of the Uinta Basin. Low temperatures (~0°C) allow HO_2NO_2 to accumulate overnight as a radical reservoir, which is then released as sunlight increases during the day. The high-NOx environment from oil and gas operations further promotes HO_2NO_2 formation through $HO_2 + NO_2 \rightarrow HO_2NO_2$. This finding is consistent with Edwards et al. (2014), who identified peroxynitric acid as an important radical reservoir and source under similar wintertime inversion conditions at the same site. We have added a sentence to Section 3.2 of the revised manuscript to clarify this physical justification.
- While HONO photolysis can be an important HOx source in many environments, its mixing ratio in the Uinta Basin is relatively low (~0.1–0.2 ppb during winter) due to the remote, oil-and-gas-dominated setting with limited vehicle traffic and urban surface sources (Li, 2024). Accordingly, HONO was not prescribed as a model input. HONO chemistry is included within MCMv331, and any HONO produced endogenously is tracked by the model, with its contribution captured within the "Other" category of the HOx budget. This is consistent with Edwards et al. (2014), who found HONO photolysis to be a modest contributor to radical production at the same site and not required to accurately simulate O3 buildup.
- The prominence of PAN decomposition as the dominant HOx source in CB6 (37.8%) compared to its negligible contribution in the other mechanisms reflects a fundamental difference in how CB6 represents organic oxidation chemistry through its carbon-bond lumping approach. We have expanded the discussion in Section

3.2 of the revised manuscript to explain this mechanistic difference and its connection to CB6's higher total HOx production rate and ultimately higher simulated O3 mixing ratios.

Some minor suggestions are listed below (line numbers refer to the revised manuscript):

• L1: The study is based on measurements in the Uinta Basin. Although the revised title is clearer, it would be better to specify the region in the title, since this study does not address general wintertime ozone pollution.

- We have revised the title to: 'Hydrocarbon and Carbonyl Contributions to Wintertime Ozone Formation in the Uinta Basin, Utah.' This more precisely reflects the geographic scope of the study.

• L13–16: The goals of the study appear somewhat complex and not very clear in the abstract.

- We have simplified and restructured the statement of goals in the abstract to more clearly reflect the logical progression of the study — from hydrocarbon emissions through carbonyl formation to O_3 production.

• L18: The phrase “showed similar trends” is vague.

- We have replaced the vague phrase 'showed similar trends' with a more specific statement in the abstract clarifying that SAPRC07 and RACM2 similarly identified formaldehyde and acetaldehyde as the dominant carbonyl contributors to O_3 production, consistent with MCMv33.

• L52–53: In the previous review, one reviewer suggested clarifying that CH_4 and HCHO are used as representative species for these reactions. While this information has now been added, the current placement in the text appears somewhat abrupt, as it is inserted between the explanations of R1 and R2, whereas reactions R6–R8 are discussed in the following paragraph. A clearer approach would be to indicate the representative species directly when introducing the reactions. For example, “(R1; methane (CH_4) as representative species, same for Rxxx)” could replace the current “(R1)” in L52. This would integrate the information more naturally with the reaction descriptions.

- We have revised the text so that the note about representative species now appears at the end of the paragraph, after all five reactions (R1–R5) have been introduced (Sec 01), rather than being inserted between reaction descriptions.
- A similar note has been added when R6–R8 are introduced later in the paragraph, clarifying that formaldehyde (HCHO) serves as the representative species for those reactions.

• L182: The authors state that species mapping was performed to convert measured organic species into the corresponding species in the lumped mechanisms, and that the species conversion database is included in the Supplementary Information. However, I was not able to locate this conversion table or database in the Supplement. Please clarify where this information can be found, or provide it if it is missing, or add the relevant references.

- We apologize for this oversight. The statement "The conversion database is included in the Supplementary Information" was an error — the database was inadvertently omitted from the submitted Supplement. We have now corrected this in two ways:

  First, the manuscript text has been updated from:

  "The conversion database is included in the Supplementary Information."

  to:

  "The species conversion database is provided as Supplementary Data File S1."

  Second, the full species conversion database has been added as Supplementary Data File S1. This file contains 18,664 rows covering the three lumped mechanisms used in this study (CB6, SAPRC07, and RACM2) and includes six columns: Mechanism, SPECIES_ID, CAS Number, Compound Name, Model Species, and Mole Ratio. The Compound Name and CAS Number columns are drawn directly from the EPA SPECIATE database version 5.2 (EPA, 2024), which is the version cited in the manuscript. The Mole Ratio column specifies how many moles of each mechanism surrogate species are produced per mole of the measured compound — for example, 1 mole of propane maps to 3 moles of PAR in CB6 (reflecting its three paraffinic carbon bonds) but to 1 mole of HC3 in RACM2 (where the whole molecule is represented by a single surrogate). This file allows full reproduction of the species mapping step without requiring access to any external database.

• L238: “CMAQ (3D photochemical model)” should be revised to “CMAQ (3D chemical transport model)”.

- We have revised 'CMAQ (3D photochemical model)' to 'CMAQ (3D chemical transport model)' in section 3.1.

• Fig. 3 and Fig. 4: I suggest using different color schemes for source and sink terms. It is generally preferable that the same color in a figure does not represent multiple processes. Expressions of “Other top 5” and “Other (<top 5)” in Fig. 3 are not recommended.

- We have revised the color schemes for Figures 3 and 4 as recommended. In the updated figures, a warm color palette is used consistently for all production bars, while a cool color palette is used for all loss bars. This makes the distinction between source and sink terms immediately clear to the reader. Additionally, the two separate "Other" categories ("Other top-5" and "Other (<top 5)") have been merged into a single "Other" category (with values summed), eliminating any potential ambiguity. No changes to the manuscript text were necessary, as the figure captions already described the grouping as a single "Other" category.

• Fig. S1–S2: Fig. S2 appears to contain the same information as Fig. S1. Therefore, Fig. S1 could potentially be removed. Please also add units to the figures.

- We thank the reviewer for this observation. While both figures contain ozone information, they serve distinct purposes — Figure S1 shows the temporal buildup of O_3 over the four-day simulation period, which is important for demonstrating day-over-day O_3 accumulation under persistent inversion conditions, while Figure S2 illustrates the negative relationship between O_3 and relative humidity, providing meteorological context for O_3 formation. To clarify this distinction, we have revised both figure captions to more explicitly describe their different purposes. We have also added units (ppb for O_3 mixing ratio and % for relative humidity) to both figures as suggested.