**General Assessment**

This manuscript presents a comprehensive modeling study of HOMs (Highly Oxygenated Organic Molecules) derived from monoterpenes using the CAM6-Chem global climate model. The authors implement a semi-explicit HOM chemical mechanism, extend the volatility basis set (VBS), and conduct a suite of sensitivity experiments to explore the impacts of branching ratios, autoxidation rates, and NOx levels on HOMs-SOA formation.

The study is timely and addresses a significant gap in the representation of HOMs in global models. The methodology is sound, and the model development is well-documented. However, a major weakness of the manuscript lies in the limited and underdeveloped discussion of the results, particularly those from the global model simulations. The current treatment of global HOMs-SOA distributions lacks the depth and detail expected for a study of this scope and importance. This significantly reduces the scientific value and interpretability of the findings.

For this reason, I recommend **major revisions**, with particular emphasis on expanding and deepening the analysis of the global model results. Additionally, improvements are needed in the clarity of some sections, including the presentation of the chemical mechanism.

**Major Comments**

1. **Expansion of the discussion on global model results**

   The current discussion of global HOMs-SOA distributions (Section 3.3) is relatively brief and lacks depth. I strongly recommend expanding this analysis and relocating it to a new Section 4 to allow for a more comprehensive and focused discussion, including:

   - A more detailed regional analysis beyond SEUS, SECN, and Amazon. For example, Europe, South Asia, and Africa are not discussed despite being relevant for OMs and/or biogenic and anthropogenic interactions.
   - A more thorough treatment of seasonality, including regional seasonal cycles and their drivers (e.g., oxidant levels, emissions).
   - A spatially resolved analysis of how HOMs-SOA distributions change across the nine sensitivity experiments. This could include difference maps or regional statistics showing the impact of branching ratios and autoxidation rates.
   - Consideration of vertical distributions of HOMs-SOA, especially given their relevance for new particle formation and cloud interactions.

2. **Clarity of Reaction Mechanism Description**

   The description of the HOMs chemical mechanism in Section 2.2.2 and Figure 1 is currently quite dense and could be made clearer with a few structural adjustments. I recommend breaking the flowchart in Figure 1 into sub-panels, each representing a distinct stage of the mechanism, and aligning the discussion in the text with these steps using corresponding subsections or paragraphs. Additionally, it would be helpful to include a summary table outlining the key reaction pathways and their roles in forming C10, C15, and C20 HOMs. Finally, I suggest adopting clearer chemical nomenclatures and ensuring that all species and acronyms used in figures and tables are clearly defined in this section.

3. **Justification for Excluding $NO_3$-Initiated HOMs**

   The manuscript excludes $NO_3$-initiated HOMs due to uncertainties. While this is understandable, recent studies suggest this pathway may be more important than previously thought. Therefore, a brief discussion of their potential importance (especially in polluted nighttime conditions) would provide a perspective for this HOM formation pathway.

**Minor Comments**

- **Lines 45–46:** The introduction discusses the role of HOMs in radiative forcing, but this is not revisited in the results. Including even a qualitative discussion in the results or conclusions on how HOMs-SOA might influence regional or global climate would enhance the impact of the study.
- **Lines 89–90:** Please provide references for the models mentioned.
- **Lines 90–95:** Include details on the simulation period used in the study.
- **Lines 99–100:** Specify the total amounts of monoterpene and isoprene emissions considered in the simulations.
- **Lines 114–115:** Please rephrase this sentence, the current wording is difficult to follow.
- **Line 125:** In addition to the vapor pressure equation, please include the gas-particle partitioning equation used in the model.
- **Line 189:** The field campaigns referenced here have not yet been introduced. Consider moving this sentence or providing context earlier.
- **Section 2.4:** This section should be expanded. Please include more details about the field campaigns, the types of measurements conducted, the instruments used, and a brief summary of key findings relevant to the model evaluation.
- **Lines 225–226:** This sentence appears more appropriate for the conclusions section rather than the results.
- **Section 3.3:** Consider moving the global model results to a new standalone Section 4 to give them greater emphasis and allow for a more structured discussion.
- **Figures 7b–7c:** Consider applying a minimum threshold for MTSOA (7b) and SOA (7c) before calculating the contributions of HOMs. Reporting high percentage contributions in regions with negligible SOA concentrations may be misleading and could skew global averages.
- **Figures 8b, 8d, 8f, 8h:** The same recommendation applies as for Figures 7b and 7c.
- **Terminology:** Ensure consistent use of terms such as "C10-NON", "C10-ON", and "HOMs-SOA" throughout the manuscript and figures.
- **Supplement:** The supplementary material is well-organized and informative. It would be helpful to reference specific tables and figures more explicitly in the main text to guide the reader.