Atmospheric Chemistry and Physics Discussions

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Comment on acp-2022-423

Anonymous Referee #1

Referee comment on "Technical note: Unsupervised classification of ozone profiles in UKESM1" by Fouzia Fahrin et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2022-423-RC1, 2022

This paper uses an unsupervised classification technique, Gaussian Mixture Modelling (GMM), to classify ozone profiles from historic and future climate simulations of the UKESM1 model. They find 6 classes of profiles, which have coherent distributions. The study then investigates how the classes change between the historic and future climate simulations, finding that the tropical classes expand in the future projections. The paper suggests that this GMM method could be useful for inter-model or model-data comparisons by enabling profiles to be grouped by coherent structures rather than set latitudes. The use of machine learning to classify ozonesondes for model comparisons is a promising approach, and the paper shows that the resulting classifications are consistent with physical interpretations of ozone variability. However, the paper could be improved by more clarity or examples on what specific advances are provided by this methodology compared to other approaches. In addition, stronger justification for some of the methodological choices is needed, as described in the comments below.

General comments:

- Since the chemical and dynamical processes controlling ozone concentrations in the stratosphere are quite different from those controlling near-surface ozone, what is the rationale for performing the GMM classification on the entire ozone profile? Could you instead cluster different vertical regions, such as stratosphere or troposphere, separately? It seems like the results might be easier to interpret and the clusters more applicable to model comparisons of specific features like surface concentration if signals from near-surface processes weren't mixed together with signals from stratospheric circulation in the creation of the clusters.
- What is the advantage of using the GMM clustering method over just grouping profiles by e.g. tropopause height or altitude of peak ozone, since these seem to be prominent features distinguishing the derived classifications? It is encouraging to see that the GMM analysis leads to results that are consistent with known sources of variability, but to justify the complexity of this GMM approach, it would be helpful to also highlight

specific cases where the GMM creates a more meaningful classification than could be obtained with a single variable such as tropopause height.

Specific comments:

- Lines 46-49: Please provide a reference.
- Lines 59-60: The discussion of previous work on ozone clustering could be expanded.
- Lines 97-98: The requirement of surface pressure reaching 1000 hPa seems like a significant limitation. Would the results be much different (and the coverage increase) if you used something like 900 hPa instead?
- Line 130: How does the pressure level standardization affect the relative importance of the stratospheric versus the tropospheric portions of the profile in determining the clusters?
- Line 149: Define BIC and refer the reader to the description in the appendix
- Lines 194-201: Do the higher tropopause and higher surface values both contribute to the definition of this cluster, or is it just that the clusters vary strongly with latitude (as shown in Fig. 4) and many other features also co-vary with latitude?
- Line 216: is mPa the right unit here?
- Line 219: Replace "reasonable" with something more quantitative
- Fig 4 (and 5) and Fig 4 caption: Does "median" make sense with respect to classifications here? Are the classes quantitatively ordered such that class 3 is in between classes 2 and 4? Also, is there much temporal variability (within the decade) in what class a particular grid box falls in? If so, it would be nice to show that since it could help clarify how the GMM classification differs from a purely latitude-based classification.
- Line 249: Does this mean the fact that class 1 has the lowest ozone, or the fact that the class 1 ozone is lower in the historic run, is consistent with the reduction with precursors?
- Lines 272-275: Is this explanation proven by your analysis or just consistent with your results?
- Lines 284-285: Please explain how this conclusion is reached from Figs 4-5
- Lines 295-297: Is it possible to relate this quantitatively to the extent of the model's Hadley cell?
- Lines 298-304: Are these results different from what would be inferred with latitudinal averages?
- Line 321: This statement needs more support. Relate to Table 4?

Technical corrections:

- Line 220: Please reword to clarify "Biomass burning in Africa produces…" or similar
- Line 249: "consistent" not "in consistency"
- Line 253: Should this say "stratosphere" or "atmosphere"?

- Lines 270-271: Please reword this sentence for clarity