Review of “Influence of Atmospheric Circulation on the Interannual Variability of Transport from Global and Regional Emissions into the Arctic” by Cheng Zheng et al. (egusphere-2024-253)

The study by Cheng Zheng and co-authors presents an analysis on transport pathways of surface emitted air pollutants into the Arctic. They employ a chemistry circulation model to assess the contribution of various source regions (with temporally fixed emissions) to the Arctic tracer mass of an idealized carbon monoxide like tracer. They come to their conclusion through analysis of tracer mass distribution in the Arctic, defined as the latitudes between 70-90 °N. More so they use empirical orthogonal functions to analyze the source of variability of the tracer mass in the Arctic. They find that the distance between the source region to the Arctic plays a crucial role for the contribution of the individual sources for the Arctic tracer mass. Another finding is that the circulation at the source region strongly impacts the contribution of the individual source regions. Sensitivities of the tracer lifetime also revealed that shorter pathways enhance the contribution of short lived species while regions with higher emissions can contribute on longer time scales to the Arctic tracer mass.

The Arctic is without doubt one of the regions most affected by current climate change. While this is obvious through temperature records, there is also strong evidence that trace species can have direct and indirect impacts on the Arctic climate. Therefore it is most important to understand how anthropogenic emissions contribute to the Arctic composition. This study directly addresses this question through a thorough analysis. The questions of the study are clearly stated. Setup of the model experiments are clearly communicated, figures are very good and the answers to the questions are based on the analysis and well justified. The paper is well written and the line of thought comes out clearly to me. The paper is in my opinion well suited for publication in ACP and I have in general only minor comments. These are outlined below.

Comments

- Definition of the “Arctic” (p.5, l.128): Is there a reason for 70°N-90°N as the Arctic? The authors also mention the polar dome? Does this latitude band reflect this dome like structure?
- Column tracer mass (p5, l.130): Is there a reason that it is the mass up to 10 hPa? Is the highest model level where tracer mass is found?
- Abbreviations (all sections): In the manuscript many abbreviations are used and I am bad at remembering these. Maybe an overview table would help here some readers (just a suggestion).
- “downstream from the jet stream” (p7, l 169): I could not really make sense out this term. What do you mean here? Is it downstream of a jet stream maximum or

downstream along the jet stream? Clearly, the jet transports tracer downstream, but also the jet can be found (almost) at every longitude in the extratropics.

- Section 3.2.2 Vertical structure: I like that an analysis of the vertical structure is part of the analysis and that the transport pathways come out as expected. I wondered if it would be possible to extend the analysis slightly. For instance, I wonder if the pathways could be distinguished more quantitatively. Is there substantial transport near the surface during winter? How much is transported within the boundary layer, free troposphere, upper troposphere and via a stratospheric pathway? In principle most of questions could be answered by some more detailed discussion of Figure 5 which I would highly appreciate.
- Methods of Section 4: The entire Section 4 is based on the EOF analysis. However, in Section 2.3 this is only introduced very briefly. I think the authors could provide a little more information on their EOF analysis in Section 2.3, this would allow readers to more easily understand the results. It could even stated which data analysis package has been used (if one has been used).
- Figures: The figures are overall of good quality. One tiny comment: they would be even better if the tick labels would be increased.