This is an interesting paper implementing microplastics into a general circulation model. The authors should be commended for their hard work. However, substantial revisions need to be included before this is publishable. A section on the uncertainties in the model could also help, as mostly this is an extrapolation of very limited data, with little discussion of what the implications are.

Major comments:

1. Table 1: please explain your definition of plastics, since usually plastics are not soluble. Please explain where you get the data for soluble plastics, since the only measurements I have seen in the literature are insoluble particles. Please show your comparisons to soluble plastics also, separately. Please discuss this more in the paper if there are no measurements why you chose to include them.

2. "The microplastic inventory is based on airborne microplastic deposition measurements collected across 11 National Park and Wilderness sites between 2017 and 2019 in the Western USA (Brahney et al., 2020)." Please explain how you use observations from the western united states to estimate global emissions. Please indicate why we should believe these extrapolations.

3. Figure 2: Why are there no fiber emissions from the ocean? What assumption does that derive from and how important is that?
4. Why are there such large emissions of microplastics from Africa? I think you might want to re-look at your emission scheme since you have as large of emissions from desert regions as population centers. Please show any data in this region that would justify these large emissions.
5. "When log-transformed, Leusch et al. (2023) demonstrate a linear increase in particle number with decreasing size." Please explain how this study extrapolated data from 5um down to nm. As far as I know, there is no robust way to measure microplastics at the nm scale, so you need more explanation here and justification of the use of this distribution. I should not have to read Leusch to understand this. It is possible you are just wildly extrapolating: that's fine, but state it clearly and it would be better to use a variety of extrapolations to see how sensitive your results are to the assumptions about size. Please also show comparisons of your results with available size data. If there is no size data, please discuss the implications.

6. "This suggests microplastic fibres need to be treated differently within the model, however they currently have the same spherical shape and settling velocities as the microplastic fragments." It sounds like you are ignoring the low settling velocity of microplastic fibers? Why don't you just pretend that they are much smaller particles instead for the settling velocity? This is really a killer: why even bother to model it if you aren't going to make sure you are modeling it as correctly as possible.

7. “Microplastic observations for model evaluation”. Please show a table of the data you have collected using your method.
8. “For active sampling 330 studies, Figure 5a shows a regional bias with most studies undertaken in Europe and Asia. The model generally simulates greater microplastic concentrations than the observations, often by a few orders of magnitude, and with a poor correlation coefficient of r = 0.35 and RMSE of 5.09 (Figure 5b). This is particularly evident across studies reporting low observed concentrations, where the model simulates a large range of microplastic concentrations.” The model does a really bad job! Since you are overpredicting the deposition rates, and overpredicting against the observations, this suggests you have a serious problem with your emissions and they should be much less.

9. “The disagreement between the model and observations is unsurprising, as observations represent a point source while the model output is the average 340 over each latitude/longitude grid cell. Regions of high spatial variability such as around urban population centres would be most impacted by this discrepancy. Furthermore, many of the observational studies to date used micro-Fourier Transform Infrared Spectroscopy (μFTIR), which can only analyse microplastics of diameter 11 μm and larger (Allen et al., 2022), i.e. it cannot resolve microplastics down to the 2.5 μm threshold of the UKESM1.1 super-coarse mode (Table 2). This also accounts for some of the differences between the observations and the model.” These reasons really aren’t convincing. Please only compare the model output to the observations in the same size bin. But most of the mass should be in the larger size bins.

Details:

1. “This degradation forms microplastics (plastic particles 1- 5000 μm) and nanoplastics (particles smaller than 1 μm), which have the potential to cause ecological damage”. Microplastics can be input to the atmosphere or other systems through other mechansims: burning or washing can also release.

2. “As a form of atmospheric aerosol, microplastics can contribute to climate change by interacting with incoming solar and outgoing thermal radiation. This in turn has an impact on the radiative balance of the atmosphere (Revell et al., 2021). Aerosols such as microplastics can also have indirect effects on radiative balance through cloud interactions and by acting as cloud con densation nuclei (CCN) (Aeschlimann et al., 2022). Clouds play an important role in the climate system (Forster et al., 2021) by reflecting sunlight to space (which has a cooling effect on Earth’s surface) and trapping thermal radiation emitted by the Earth (which has a warming effect). In general, clouds that have been perturbed by aerosols consist of more numerous and smaller cloud droplets, so that they reflect more sunlight and are longer lived (Twomey, 1977; Albrecht, 1989). “ This paragraph should be rewritten. Revell et al., 2021 clearly showed

that microplastics can be neglected for their radiative impact, and even if the impact is 100x higher (which would be hard), it will stay pretty much irrelevant. Similarly the number concentration of microplastics is unlikely to make it important for cloud condensation nuclei. So the only possible interaction with climate that can be important is Ice nucleation. Please rewrite this paragraph and combine it with the next so it doesn't pretend that microplastics are more important than they are for climate interactions.

3. "Microplastics have also been collected in cloud water (Xu et al., 2024; Wang et al., 2023), indicating their uptake into clouds occurs and that microplastics potentially act as cloud condensation nuclei (CCN)." Or, more likely, are taken up by falling rain drops.

4. Table 3: how does your model compare to other modeling studies in the literature, some of which are only regional, but many of which exist? For lifetime and sources, etc, and for different regions and concentrations. Please place your study in the context of the existing literature.
5. Figure 5: why do you not use the Brahney et al,. 2020 deposition data to compare against your observations? Please list all the citations of the measurements in table.
6. "Assessing the vertical transport of microplastics indicates that the smaller microplastics are well mixed in the troposphere," well mixed means that there is no vertical gradient: I don't think that's what you show. Please remove that phrase.

7. "Compared to total aerosol number concentrations, microplastics currently contribute a minor fraction (Table 4)." Minor is an overstatement: microplastics are neglible.