Atmospheric Chemistry and Physics Discussions

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# Comment on acp-2022-310

Anonymous Referee #2

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Referee comment on "The unexpected high frequency of nocturnal surface ozone enhancement events over China: characteristics and mechanisms" by Cheng He et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2022-310-RC2, 2022

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This paper presents a large dataset of the dynamics of nocturnal O3 in China with a special emphasis on the frequency with which nighttime concentrations are observed to increase (nocturnal ozone enhancements or NOEs). While I think there are useful results here, the paper would benefit from substantial editing to improve clarity and conciseness. I recommend publication after the following comments have been addressed.

Major comments:

- I recommend reframing the motivation behind this study. As written the introduction seems to argue that these NOEs are interesting because of their effects on health (of humans, plants, etc) but, at least in China, the maximum levels observed during NOEs are really very low (17 ppb in winter, 37 ppb in the summer) for health effects, especially as they occur during a time of day when most humans are asleep indoors and plants are more dormant. Do you have references that show those concentrations being associated with negative health outcomes? I don’t mean to say at all that we shouldn’t try to understand the full daily cycle of O3 and the effects of vertical mixing on nighttime levels, just that it rings hollow to present it as if the NOEs themselves are a major source of concern. I also found it a bit odd that there seems to be more focus given to the frequency of occurrence of increases than to the concentrations themselves.
- Similarly, I don’t find the lengthy discussion of differences in frequency of occurrence of nocturnal ozone increases between the US, Europe and China compelling. In the US and Europe there are generally lower daytime O3 peaks (which leaves a smaller enhancement in the residual layer) and, I think, fewer nocturnal NO emissions (which results in less complete titration at night) so that the difference between the surface and the residual layer is less stark and mixing has a smaller effect. What really matters is probably the 24 hour integrated O3 exposure, which is much higher in most of China than in the EU or US, possibly exacerbated by trends of increasing NOEs over time? But not by a ton (at least not yet since the nocturnal O3 is so low). And the nighttime exposures in the EU and US are comparably more important because the nighttime O3

levels are higher and the daytime peaks lower (generally). You do eventually get there towards the end of the manuscript but I think the whole paper would be improved if you discuss the logical explanations for these broad differences when you are describing the observed distributions.

- Also related to point #2 above, I appreciate the usage of odd oxygen in your analysis but it seems like an afterthought right now and I think you should introduce it earlier (for example, it could logically be used in discussing the observed differences in nocturnal O3 behavior between the EU, the US and China.)
- NNOE (non-nocturnal ozone enhancement) is a weird acronym because it sounds like it should be an enhancement that happens during the day rather than a lack of an enhancement at night. Perhaps "non-enhanced nocturnal ozone" or "stable nocturnal ozone event" would work better?
- I would encourage the authors to think about whether certain points could be made using correlation plots rather than color-scaled maps that the reader must qualitatively compare. I had to do a lot of scrolling back and forth to see some of the trends that were being described. The top rows of Figures 1 and 2 make sense as color-scaled maps but when you are trying to compare NOE frequency to nocturnal ozone concentrations and subsequent-day afternoon O3 I think those would be much better communicated by correlations. Actually the relationship between NOE frequency and afternoon ozone is less direct than looking at, for example, peak O3 in a NOE compared to O3 from the day before (or the following day). Why not plot those correlations instead? Similarly, I find that Figure 3 takes more effort than it should to look at. Would it communicate the same thing if you showed a single map that was colorscaled by the mean enhancement observed for evenings on which an NOE occurred? I believe the main point is that the sites that have the most frequent NOEs also experience the largest O3 increases when they occur. Or perhaps that could also be a correlation plot.
- When looking at vertical profiles (eg section 3.2 and Figure 6), I think potential temperature might show your point better in terms of highlighting the altitude range that is being affected by cooling at the surface.
- I wonder if you have considered the effects of reactions between NO2 and O3 to form NO3 and N2O5 in the surface layer? NO3 is quite reactive and N2O5 has a high deposition velocity so it could be an appreciable fraction of the observed nighttime O3 decreases. I would consider it part of "NOx titration of O3" but I don't think I saw this process mentioned explicitly anywhere. If it has not been considered it certainly should be. NO3 is highly reactive and N2O5 deposits very easily so they both could be substantial as a nocturnal Ox loss.
- Does it matter that sunrise and sunset is at a different time of day across different latitudes (or between the cold and the warm season)? It seems like defining nighttime in terms of clock time rather than solar time could bias things, especially increases that are observed in the early morning in the summer when you might have sunlight for the beginning of commuting time. I'm thinking especially of the NOE events assigned to have happened between 8 and 9 pm and 4 and 5 am.
- I recommend trying to cut down on the figures that accompany the case studies. I don't think the main finding, that vertical mixing can largely explain the observed NOEs is particularly controversial so I think it should be sufficient to describe briefly the particular instances that were investigated and the consistency between them but I don't think this requires the 1-2 figures per event that are currently shown.

More minor issues:

In the abstract, I was initially confused about what an annual mean frequency of 41% meant. After reading I believe that you calculate the annual frequency of NOEs for each site and then average across all sites. While I think changing to "mean annual frequency" would be slightly clearer, I would encourage the authors to also describe this number in slightly more detail to make things easier on the reader as I started wondering early on which locations were used for each dataset.I would include a reference to S1 (the map of locations) around line 92 rather than only in the paragraph before.

Figure 1: I don't see how the inset shows mean and standard deviation.

Figure 2: Please label the colorscale for panels c and d. It's in ppb I think? But with the upper one % and the lower one not it is a bit confusing. Same issue with the inset as for Figure 1. In general I think insets, unless they are simply zoomed in on a particular region of the larger panel, should have their own axis labels, otherwise they are very hard to interpret.

Figure 4: Error bars would be good. Some of those profiles don't look super different for NOEs and NNOEs. And I would recommend that you harmonize axes for all sites in figure 4 if possible.

Line 228, I find this sentence confusing. I can see how surface layer Ox should be comparable to residual layer Ox. And surface layer Ox would be similar to residual layer O3 if NO2 were a small fraction of the residual layer Ox but do we know that a priori? Also, I don't think nighttime emissions of NO need be small for this relationship to hold because it simply converts O3 into NO2 on a one to one basis and thus conserves Ox.

Figure 5 is another place where I think error bars would help. These differences look pretty big, I don't really understand how it can be that there isn't a significant difference in U* or PBLH between NOE and NNOE evenings. Need to look at figures from supplement.

Figure 6 – I believe this must be model data given the smoothness of the lines and your previous use of U* and PBLH from the model. But I think it would be worth clarifying that here.

Your text goes right from Figure 9 to Figure 11. I recommend moving Figure 10 to wherever it is that you discuss it or removing it if it is not currently discussed in the text.

Figure S1: the red dots are nearly invisible. Recommend marking with stars or some other symbol that will stand out in both shape and color and making them a bit bigger.

Figure S2: The legend says that the inset shows the number of sites with positive trend but I don't really understand what I'm looking at. As displayed I don't think these are useful and, since I don't know what you're trying to communicate, I can't figure out how to help.

English language – quite a few instances including from the first few pages (but not limited to):

line 62, threat should be threaten

top of p3: only one or A few and A comprehensive view on (del "the") general characteristics and mechanisms of (del "the")…

Line 71: six years OF ozone…